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Microsoftware for Facility Layout

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MICROSOFTWARE FOR FACILITY LAYOUT

BY

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THESIS

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ABSTRACT

This study presents five supporting programs in the area of facility layout design. Programs are "stand alone" adapted type which cover data analysis and analytical techniques. Programs are From/To (From/To Chart generator), CRAFT* (Computerized Relative Allocation of Facilities Technique), RELVAL (Relationship Chart generator), CORELAP* (Computerized Relationship Layout Planning), and EVAL (Layout Evaluation program). Theory, complete program documentation, and case example for each program are presented. Programs are written in an interactive basic mode and have been tested on the Apple II Plus system.

* CRAFT, CORELAP are heuristic techniques for plant design.

To my parents,

James W. Anderson and Virginia Anderson

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CHAPTER I

INTRODUCTION

Facility layout is an area of considerable interest to most industries. Due to modern technology and the increasing number of data variables and constraints involved in the designs, better approaches of developing layout designs are warranted. The development of heuristic analytical approaches has proved effective in producing better designs. In conjunction with these complex techiques, computers in general and microcomputers in particular are being used in this paper in solving layout design problems. A number of microcomputer programs are documented with case example to demonstrate their use in the area of layout arrangement.

Microcomputers Vs. Larger Counterparts

With the advance of technology, the processing power, reliability, size, and speed of the microcomputer has improved remarkably. Furthermore, the cost of a microcomputer system has dropped significantly [9].

Although microcomputers and large computers are similar in many ways, microcomputers do have characteristics that distinguish them from large general-purpose computers. Microcomputers are small, inexpensive, and personal. Presently, microcomputers are not "yet"

recommended for applications requiring large data base or high Input/Output rates, which characterize most large commercial processing jobs. However, the capability of microcomputers has increased by the addition of more memory, peripherals, and software so that some configurations offer almost all the capabilities of larger systems for cases of "stand alone" programs which characterize many industrial engineering techniques [1], [5].

Practicing Industrial Engineers will find it beneficial to obtain an inexpensive microcomputer to solve medium to small size problems within their department, such as facility layout and production departments arrangement. Rapid changes in industry, product variations, product volume, and other factors require continuous analysis and evaluation of existing layout with respect to meeting the requirements of such changes. This information, along with its cost, is required by management in the decision process pertinent to production systems. This information should be readily available for cases such as accepting or rejecting offers of producing new products, or shop scheduling in production plants. Use of microcomputers could result in quicker, cheaper, and more effective analysis of layout changes if the supporting software is available [1].

This study presents five supporting programs in the area of facility layout, that will aid the designer using a microcomputer to analyze his/her data and apply known analytical techniques resulting in an effective layout.

Existing computer assisted layout techniques can be classified into two main categories: Construction type algorithm, in which the arrangement of departments starts without an initial layout and uses the program logic until a layout design is achieved. The second category referred to as the improvement-type algorithm, requires an initial layout as input and the rearrangement of the different departments of the layout occurs in order to obtain an improved layout design.

Organization of the Study

The next five chapters document 5 programs used in the facility layout arrangement. Each program is documented through the theory behind it, function of the program, input requirements, logic, code, and the output. Use of the programs are demonstrated through an example at the end of each chapter.

Chapter II presents a data analysis program. From/To Chart is a program which provides information concerning the number of handling trips made between each department center of activity. This analysis is based on different sequences of operations for a number of products with varying quantities and handling batch sizes.

Chapter III presents a layout improvement program. CRAFT (Computerized Relative Allocation of Facilities Technique) seeks an optimum design, with respect to cost of material handling, by making improvements in an existing layout. CRAFT uses a pairwise exchange routing as its basic technique.

Although Chapters II & III are documenting two separate programs, the user can use them as one unit, i.e., the From/To Chart produces the information needed as input for CRAFT.

Chapter IV presents a data analysis program. REL Chart is a management tool designed to facilitate considerations of qualitative factors in their designs. The REL Chart replaces the quantitative data in a From/To Chart by qualitative closeness ratings.

Chapter V presents a construction program. CORELAP (Computer (Computerized Relationship Layout Planning) considers the qualitative factors influencing the arrangement of departments as represented in the REL Chart, and produces a closeness rating value for each department which is used in the departmental arrangement.

Although Chapters IV & V are documenting two separate programs, the user can use them as one unit, i.e., the REL Chart produces the information needed as input for CORELAP.

Chapter VI presents a layout evaluation program and provides guidelines for rearrangement with respect to satisfying closeness ratings. Programs are designed in a way such that no programming experience is required by users. Instructions are given on how to use the program, input data, and select program options. Computer memory space for data storage is allocated according to the size of the user's problem and is limited only by the capacity of the microcomputer in use. Programs are written in Applesoft Basic computer language, which makes it directly usable on an Apple II microcomputer system. Minor adjustments are required in the code

to make it usable on other systems.

CHAPTER II

FROM/TO CHART

Introduction

The From/To Chart, also referred to as a travel chart and a cross chart, is an adaptation of the familiar mileage chart appearing on most road maps. Typically, the From/To Chart provides information concerning the number of material handling trips made between two centers of activity. It is used by the industrial engineers in designing and analyzing production plants. Its primary use is in the departmental arrangement and in the computation of material-handling cost [4].

Products are moved between departments in batches. During this process there may be variations in volumes to produce, differences in batch sizes, and the sequence of operation for each part. In cases like this, microcomputers can greatly reduce the computational effort of number of trips made by material handling equipment used and consequently the cost of handling.

The analyst assumes that the material-handling cost is proportional to the number of trips exchanged between departments when using the From/To Chart for departmental arrangement. Because of this proportionality, the departments should be arranged in a way that will increase the proximity between "active" departments [5].

(activity with respect to the number of trips exchanged between departments).

The cost(s) per trip is dependent on the distance traveled. If this cost and a unit distance between different departments are known, then the total cost of material handling for a specific arrangement can be computed.

From/To Charts are used in conjunction with process layouts and have been found to be useful in the following:

1. "Selling" the layout arrangement to the management.
2. Analyzing material movement.
3. Developing departmental block plans.
4. Developing detailed layout arrangements.
5. Evaluating layout alternatives.
6. Demonstrating the dependency of one area upon another.
7. Improving the use of floor space.
8. Showing interrelationship of product lines.

Program Documentation

Program Name: From/To Chart.

Program Function: The From/To Chart provides the number of material-handling trips made between each two departments in a production plant.

Program Input:

1. Number of product types to be produced.
2. Number of production departments.
3. The quantity associated for each part/product.
4. The batch size associated for each part/product.
5. The sequence of operations associated for each part/product expressed in department numbers.

Program Logic:

1. Accept input.
2. Display data, make corrections if any, if not, continue.
3. For each product/part, the # of trips are computed.

   # of trips = quantity/batch size.
4. In a matrix NXN (Where N = No. of departments involved), the # of trips exchanged between each two departments are accumulated, based on scanning the sequence of operations for each product/part.
5. Make modifications in input data or exit program.

Program Output: From/To Chart with respect to the product (Refer to the case example).

* Self explanatory messages are displayed when the wrong data type is used.

Program Listing

```
10  REM  **PLANT LAYOUT-FROM/TO C
     HART
15  GOSUB 475
20  CLEAR
25 Z% = 0
30  PRINT : PRINT : PRINT
35  INPUT "ENTER # OF PARTS TO BE
      PRODUCED ";NP
40  DIM P(NP,50),Q(NP),B(NP),TP(N
     P),N(NP)
45  PRINT
50  INPUT "ENTER # OF PRODUCTION
     DEPARTMENTS ";ND
55  DIM DD(ND,ND)
60  PRINT
65  HOME
70  PRINT "FOR EACH PART ENTER:"
75  PRINT : PRINT "     QUANTITY,
     BATCH SIZE,SEQUENCE"
80  PRINT "      OF OPERATIONS"
85  PRINT : PRINT "NOTE:": PRINT

90  PRINT "    1- USE DEPT.#'S FO
     R OPERATIONS": PRINT
95  PRINT "    2- USED DEPT.#'S C
     AN NOT EXCEED ";ND
100  PRINT
105  PRINT "    3- ENTER '0' TO E
     ND OPERATIONAL SEQ."
110  PRINT : PRINT "    4- # OF O
     PERATIONS CAN NOT EXCEED": PRINT
     "        50 PER PART "
115  PRINT : PRINT : PRINT : PRINT

120  PRINT : PRINT : INPUT "HIT R
     ETURN WHEN READY ";Y$
125  HOME
130  FOR J = 1 TO NP
135  GOSUB 140: GOTO 235
140 N(J) = 0:B(J) = 0
145  PRINT "PART # ";J
150  INPUT "ENTER QUANTITY ";Q(J)

155  INPUT "ENTER BATCH SIZE ";B(
     J)
160  IF B(J) = 0 THEN  PRINT "BAT
     CH SIZE CAN NOT BE 0, REENTE
     R": GOTO 155
165  FOR I = 1 TO 50
```

```
170  PRINT "ENTER DEPARTMENT # FO
     R OPERATION ";I;
175  INPUT " : ";P(J,I)
180  IF P(J,I) > ND THEN  PRINT "
     DEPARTMENT # EXCEEDS THE # O
     F DEPTS.": PRINT "REENTER": GOTO
     170
185  IF I > 1 THEN I1 = I - 1
190  IF P(J,I) = P(J,I1) THEN  PRINT
     "TRIPS CAN NOT BE INSIDE SAM
     E DEPARTMENT": PRINT "REENTE
     R": GOTO 170
195  IF P(J,I) = 0 THEN 215
200 N(J) = N(J) + 1
205  NEXT I
210  PRINT : PRINT
215  PRINT : INPUT "DO YOU WANT T
     O MAKE CHANGES, (Y OR N)?";B
     $: IF B$ = "N" THEN 230
220  GOSUB 520
225  GOTO 215
230  RETURN
235  HOME
240  NEXT J
245  REM ** #TRIPS BETWEEN DEPTS
     ARE CALCULATED
250  HOME : PRINT : PRINT
255  PRINT "   YOUR COMPUTER IS C
     ALCULATING": PRINT "       P
     LEASE STAND BY"
260  FOR J = 1 TO NP
265 T = Q(J) / B(J):I% = T:R = T -
     I%
270  IF R = 0 THEN TP(J) = T: GOTO
     280
275 TP(J) = I% + 1
280  NEXT J
285  FOR J = 1 TO NP
290 M = N(J) - 1
295  FOR I = 1 TO M
300 I1 = I + 1
305 J1 = P(J,I):J2 = P(J,I1)
310 DD(J1,J2) = DD(J1,J2) + TP(J)

315  NEXT I
320  NEXT J
325  HOME : GOSUB 330: GOTO 425
330  PRINT "          FROM/TO CHAR
     T": PRINT "        UNITS: #
     OF TRIPS"
```

```
335  PRINT "          ------------
     ----": PRINT
340 IC = 0
345  FOR I = 1 TO ND
350  PRINT "FROM DEPT. ";I
355  FOR J = 1 TO ND
360  PRINT "        TO DEPT. ";J;"
      # OF TRIPS= ";DD(I,J)
365  IF Z% = 1 THEN 400
370 IC = IC + 1
375  IF IC < 12 THEN 400
380  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
385 IC = 0
390  IF J = ND THEN  HOME : GOTO
     400
395  HOME : PRINT "FROM DEPT. ";I

400  NEXT J
405  NEXT I
410  IF Z% = 1 THEN 420
415  PRINT : INPUT "HIT 'RETURN'
     TO CONTINUE ";Y$: HOME
420  RETURN
425  HOME
430  PRINT "NEXT STEP TO BE PERFO
     RMED :"
435  PRINT "     1. EXIT PROGRAM"
440  PRINT "     2. MODIFY EXISTIN
     G DATA"
445  PRINT "     3. INPUT NEW DATA
     "
450  PRINT : PRINT : PRINT
455  PRINT "   ENTER CHOICE # ": GET
     X
460  ON X GOTO 470,600,15
465  PRINT "CHOICE MUST BE 1,2, O
     R 3": GOTO 425
470  HOME : END
475  HOME : FOR X = 1 TO 5: PRINT
     : NEXT X
480  PRINT "             PLANT DES
     IGN"
485  PRINT "             FROM/TO C
     HART"
490  PRINT
495  PRINT "            IEMS DEPAR
     TMENT"
500  PRINT "     UNIVERSITY OF CE
     NTRAL FLORIDA"
```

```
505  FOR X = 1 TO 3000: NEXT X: HOME

510  RETURN
515  STOP
520  FOR J = J TO NP:N(J) = 0
525  PRINT : PRINT : PRINT : PRINT

530 A$(1) = "QUANTITY ":A$(2) = "
     BATCH SIZE ":A$(3) = "DEPT.
     # OF OPERATIONS "
535  FOR X = 1 TO 3: PRINT X;". "
     ;A$(X): NEXT X
540  PRINT : PRINT : PRINT "ENTER
      # OF ITEM TO BE CHANGED ": PRINT
     : INPUT X
545  IF X = 1 THEN 560
550  IF X = 2 THEN 565
555  IF X = 3 THEN 570
560  PRINT : INPUT "ENTER NEW VAL
     UE FOR QUANTITY ";Q(J): RETURN

565  PRINT : INPUT "ENTER NEW VAL
     UE FOR BATCH SIZE ";B(J): RETURN

570  FOR I = 1 TO 50
575  PRINT "ENTER NEW DEPT. # OF
     OPERATION ";I;
580  INPUT " : ";P(J,I)
585  IF P(J,I) = 0 THEN  RETURN
590 N(J) = N(J) + 1: NEXT I
595  RETURN
600  GOSUB 605: GOTO 250
605  HOME : PRINT : PRINT : PRINT

610  PRINT "ENTER PART# FOR WHICH
      DATA": INPUT "TO BE MODIFIE
     D (0 TO CONTINUE) ";J
615  IF J = 0 THEN 625
620  GOSUB 140: GOTO 605
625  RETURN
```

Case Example

A company consists of seven production departments (#1 through #7). Products are classified into five groups with each having to pass through a specific operation sequence. Table 2.1 displays the volume of production of each group (PSC), the bulk factor (Batch size or pieces/load (PSC/L)), and the operation sequence.

TABLE 2.1

PRODUCT INFORMATION

GROUP #	VOLUME (PCS)	BULK FACTOR (PCS/L)	OPERATION SEQUENCE (DEP. #)
1	700	7	1, 5, 4, 3, 7
2	12	1	1, 3, 2, 6, 7
3	1000	20	1, 5, 7
4	390	30	1, 2, 3, 4, 5, 6, 7
5	77	7	1, 5, 2, 3, 7

After loading the program and typing RUN, the screen displays the following

RUN

PLANT DESIGN
FROM/TO CHART

IEMS DEPARTMENT
UNIVERSITY OF CENTRAL FLORIDA

This case example involves the manufacturing of five product/part types within seven production departments. The program begins with the following questions:

```
ENTER # OF PRODUCT/PART TYPES
TO BE PRODUCED 5

ENTER # OF PRODUCTION DEPARTMENTS 7
```

This is followed by a brief statement of program instructions.

```
FOR EACH PART ENTER:

     QUANTITY,BATCH SIZE,SEQUENCE
     OF OPERATIONS

NOTE:

     1- USE DEPT.#'S FOR OPERATIONS

     2- USED DEPT.#'S CAN NOT EXCEED 7

     3- ENTER '0' TO END OPERATIONAL SEQ.

     4- # OF OPERATIONS CAN NOT EXCEED
        50 PER PART



HIT RETURN WHEN READY
```

The required data is now entered.

```
PART # 1
ENTER QUANTITY 100
ENTER BATCH SIZE 7
ENTER DEPARTMENT # FOR OPERATION 1 : 1
ENTER DEPARTMENT # FOR OPERATION 2 : 5
ENTER DEPARTMENT # FOR OPERATION 3 : 4
ENTER DEPARTMENT # FOR OPERATION 4 : 3
ENTER DEPARTMENT # FOR OPERATION 5 : 7
ENTER DEPARTMENT # FOR OPERATION 6 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?Y
```

The opportunity to edit the data is given after entering data for each product group. The correction options are displayed:

```
1. QUANTITY
2. BATCH SIZE
3. DEPT. # OF OPERATIONS
```

Corrections are made by entering the number of the item to be changed and the corresponding value.

```
ENTER # OF ITEM TO BE CHANGED

?1

ENTER NEW VALUE FOR QUANTITY 700
```

The remaining data is now entered.

```
PART # 2
ENTER QUANTITY 12
ENTER BATCH SIZE 1
ENTER DEPARTMENT # FOR OPERATION 1 : 1
ENTER DEPARTMENT # FOR OPERATION 2 : 3
ENTER DEPARTMENT # FOR OPERATION 3 : 2
ENTER DEPARTMENT # FOR OPERATION 4 : 6
ENTER DEPARTMENT # FOR OPERATION 5 : 7
ENTER DEPARTMENT # FOR OPERATION 6 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
PART # 3
ENTER QUANTITY 1000
ENTER BATCH SIZE 20
ENTER DEPARTMENT # FOR OPERATION 1 : 1
ENTER DEPARTMENT # FOR OPERATION 2 : 5
ENTER DEPARTMENT # FOR OPERATION 3 : 7
ENTER DEPARTMENT # FOR OPERATION 4 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
PART # 4
ENTER QUANTITY 390
ENTER BATCH SIZE 30
ENTER DEPARTMENT # FOR OPERATION 1 : 1
ENTER DEPARTMENT # FOR OPERATION 2 : 2
ENTER DEPARTMENT # FOR OPERATION 3 : 3
ENTER DEPARTMENT # FOR OPERATION 4 : 4
ENTER DEPARTMENT # FOR OPERATION 5 : 5
ENTER DEPARTMENT # FOR OPERATION 6 : 6
ENTER DEPARTMENT # FOR OPERATION 7 : 7
ENTER DEPARTMENT # FOR OPERATION 8 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
PART # 5
ENTER QUANTITY 77
ENTER BATCH SIZE 7
ENTER DEPARTMENT # FOR OPERATION 1 : 1
ENTER DEPARTMENT # FOR OPERATION 2 : 5
ENTER DEPARTMENT # FOR OPERATION 3 : 2
ENTER DEPARTMENT # FOR OPERATION 4 : 3
ENTER DEPARTMENT # FOR OPERATION 5 : 7
ENTER DEPARTMENT # FOR OPERATION 6 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
```

While the computer is calculating the number of trips between departments, the program will display

```
YOUR COMPUTER IS CALCULATING
    PLEASE STAND BY
```

For the period in which computation is taking place. The results are then displayed to the user.

```
          FROM/TO CHART
        UNITS: # OF TRIPS
         ----------------

FROM DEPT. 1
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 13
        TO DEPT. 3 # OF TRIPS= 12
        TO DEPT. 4 # OF TRIPS= 0
        TO DEPT. 5 # OF TRIPS= 161
        TO DEPT. 6 # OF TRIPS= 0
        TO DEPT. 7 # OF TRIPS= 0
FROM DEPT. 2
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 0
        TO DEPT. 3 # OF TRIPS= 24
        TO DEPT. 4 # OF TRIPS= 0
        TO DEPT. 5 # OF TRIPS= 0
        TO DEPT. 6 # OF TRIPS= 12
        TO DEPT. 7 # OF TRIPS= 0
```

```
FROM DEPT. 3
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 12
        TO DEPT. 3 # OF TRIPS= 0
        TO DEPT. 4 # OF TRIPS= 13
        TO DEPT. 5 # OF TRIPS= 0
        TO DEPT. 6 # OF TRIPS= 0
        TO DEPT. 7 # OF TRIPS= 111
FROM DEPT. 4
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 0
        TO DEPT. 3 # OF TRIPS= 100
        TO DEPT. 4 # OF TRIPS= 0
        TO DEPT. 5 # OF TRIPS= 13
        TO DEPT. 6 # OF TRIPS= 0
        TO DEPT. 7 # OF TRIPS= 0
FROM DEPT. 5
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 11
        TO DEPT. 3 # OF TRIPS= 0
        TO DEPT. 4 # OF TRIPS= 100
        TO DEPT. 5 # OF TRIPS= 0
        TO DEPT. 6 # OF TRIPS= 13
        TO DEPT. 7 # OF TRIPS= 50
FROM DEPT. 6
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 0
        TO DEPT. 3 # OF TRIPS= 0
        TO DEPT. 4 # OF TRIPS= 0
        TO DEPT. 5 # OF TRIPS= 0
        TO DEPT. 6 # OF TRIPS= 0
        TO DEPT. 7 # OF TRIPS= 25
FROM DEPT. 7
        TO DEPT. 1 # OF TRIPS= 0
        TO DEPT. 2 # OF TRIPS= 0
        TO DEPT. 3 # OF TRIPS= 0
        TO DEPT. 4 # OF TRIPS= 0
        TO DEPT. 5 # OF TRIPS= 0
        TO DEPT. 6 # OF TRIPS= 0
        TO DEPT. 7 # OF TRIPS= 0

HIT 'RETURN' TO CONTINUE
```

Finally, program options are now displayed

```
NEXT STEP TO BE PERFORMED :
     1. EXIT PROGRAM
     2. MODIFY EXISTING DATA
     3. INPUT NEW DATA


   ENTER CHOICE #
```

From \ To	1	2	3	4	5	6	7
1	0	13	12	0	161	0	0
2	0	0	24	0	0	12	0
3	0	12	0	13	0	0	111
4	0	0	100	0	13	0	0
5	0	11	0	100	0	13	50
6	0	0	0	0	0	0	25
7	0	0	0	0	0	0	0

Figure 2.1. From/To Chart summarizing number of material handling trips per day between departments using case example.

CHAPTER III

CRAFT

Introduction

CRAFT (Computerized Relative Allocation of Facilities Techniques) was originally presented by Armour and Buffa [2]. This program is considered an improvement type as it requires an initial input arrangement. The criterion employed in CRAFT is the minimization of the cost of material handling, where this cost is expressed as a linear function of distance traveled. Input requirements for CRAFT include:

1. Initial layout arrangement showing all departments.
2. Number of trips between the departments.
3. Cost of one trip a unit distance between departments.

CRAFT attempts to make improvements in the initial layout in a sequential fashion. It evaluates the given layout by calculating the cost of material movement, then it considers the effect of interchanging the departments locations. If improvements can be made by making pairwise exchanges, the exchange producing the greatest improvement is made. The process continues until no improvement can be made by pairwise exchanges. This procedure may be characterized as a steepest-descent procedure because it makes that interchange which results in the greatest decrease in the

total cost [3] (refer to Figure 3.5).

Advantages of CRAFT

1. The developed layout usually results in an improvement over the initial layout with respect to material-handling cost.

2. CRAFT's evaluation technique proved to be efficient only with respect to quantifiable criteria.

Limitations of CRAFT

1. The algorithm is path-oriented with respect to the initial arrangement (i.e. The result is not necessarily optimal).

2. Craft uses the department centers in measuring the trip distances, which are not realistic for some applications (refer to Figure 3.1).

3. The original CRAFT algorithm used in main frame computers usually produces an output with "zig-zagging" departmental boundaries which might require effort in correcting and readjusting these boundaries to an acceptable arrangement (refer to Figure 3.2).

4. CRAFT deals with quantifiable criteria, neglecting any qualitative factors affecting the design.

5. The improvements from the algorithm are a result of the assumption that the cost of movement has a direct linear relationship with the distance.

Microsoftware Adaptation For CRAFT Pairwise Exchange Technique

Due to limitations which exist for the microcomputers (memory limitation, speed, etc.), and considering the case of production

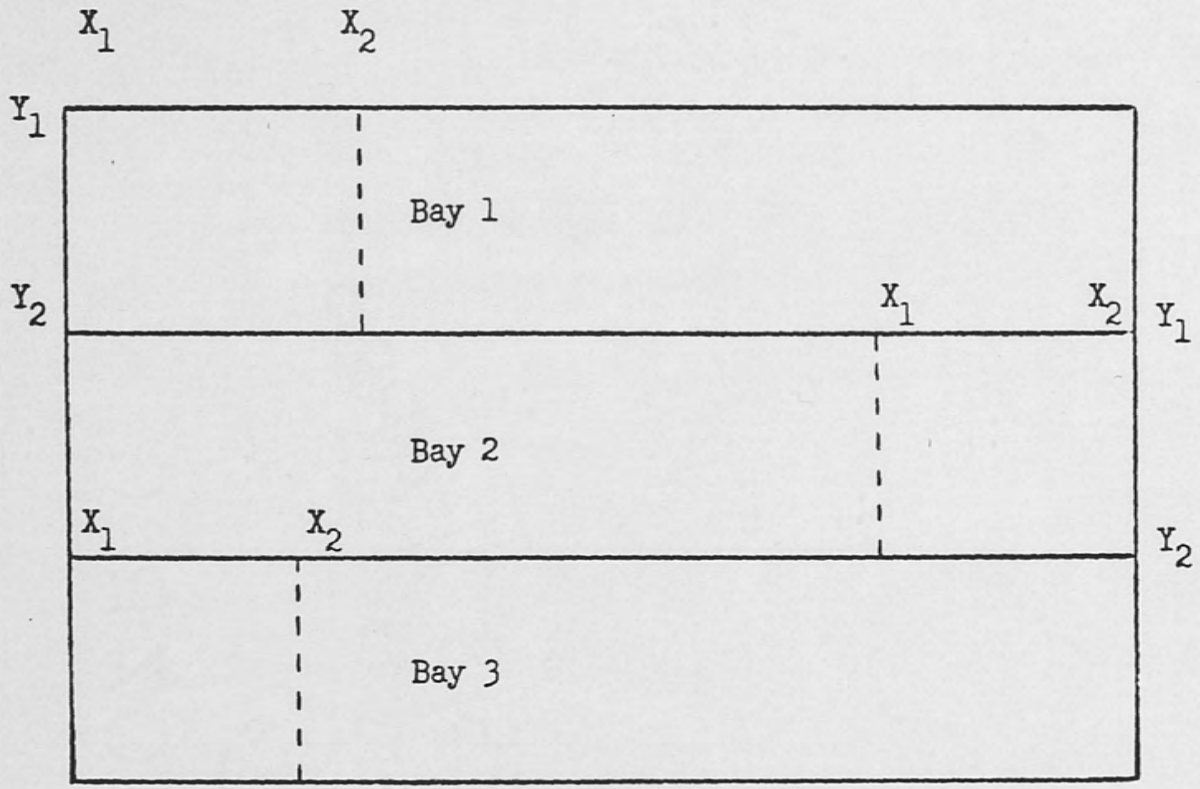


Figure 3.1. Rectangular area coordinates key.

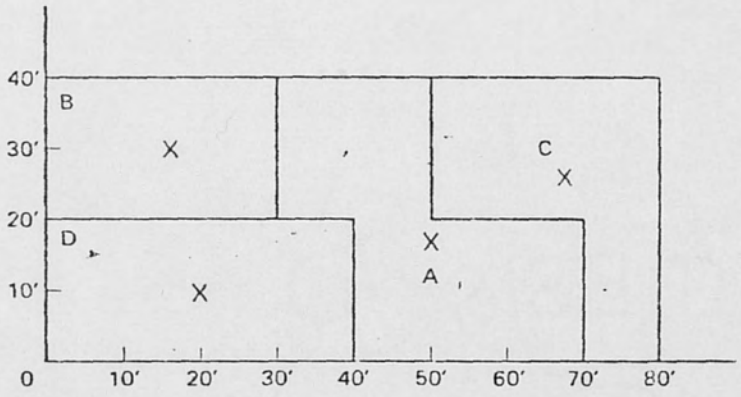


Figure 3.2. Location pattern displaying "zig-zagging" boundaries of a layout arrangement.

plants where departments are usually arranged in bays served by common material handling equipment, a new method to input the initial layout arrangement was developed [4]. The method is summarized in the following points:

1. Plant is considered rectangle in shape, with the user supplying its width and length, i.e., total area available.

2. Plant departments are arranged in bays, with the user supplying the bay area and number.

3. Considering the previous points, the user enters his initial arrangements naming the "Northwest Corner" department as the first department number and supplies its area. The user then proceeds by naming the departments following the arrow sequence shown in Figure 3.3 (i.e., for the example in Figure 3.3 the user enters 3,15,2,10,9 as the sequence of departments along with the corresponding area of the departments).

It is the function of the program to translate this information into an initial layout and proceed with the computation. It is believed that by using this method, a good amount of work of eliminating the "zig-zagging" of main frame CRAFT is avoided, as well as accomodation of a program the size of CRAFT by the micro-computer. The program also considers the rectilinear distance in computing the distance between two departments (refer to Figure 3.4).

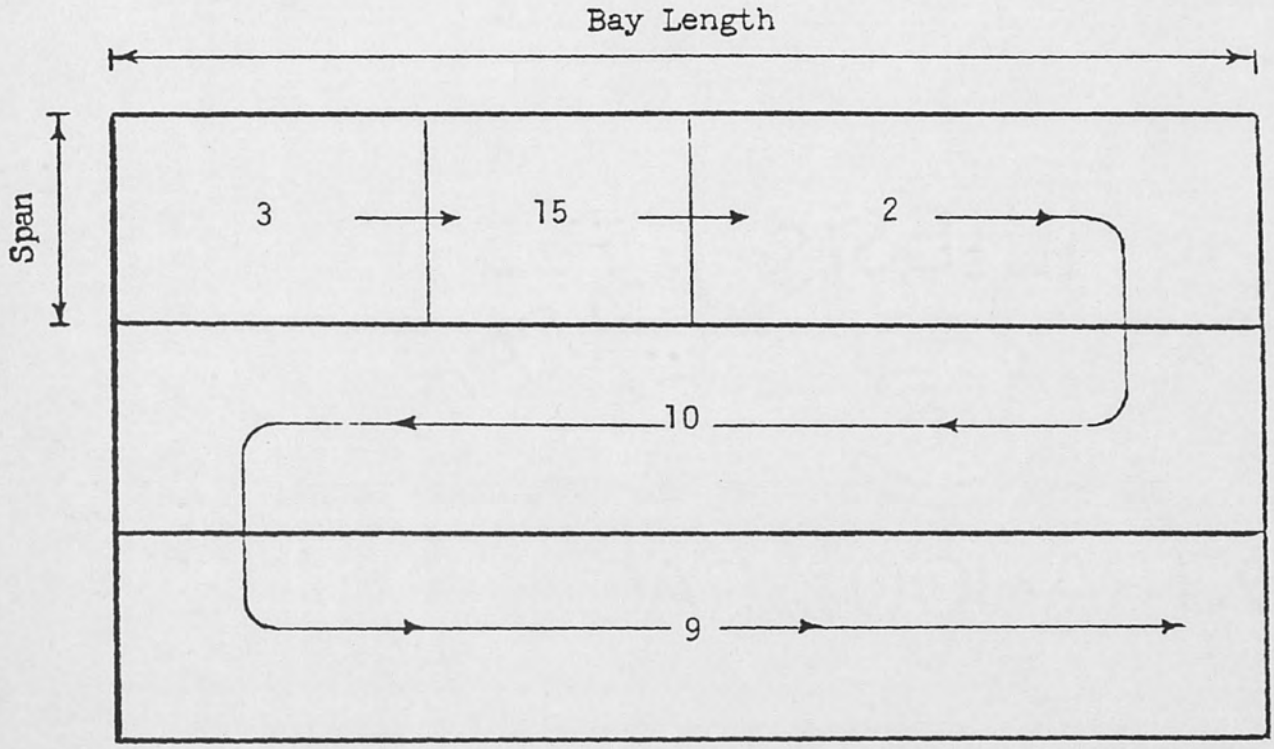


Figure 3.3. Departmental sequence into plant bays.

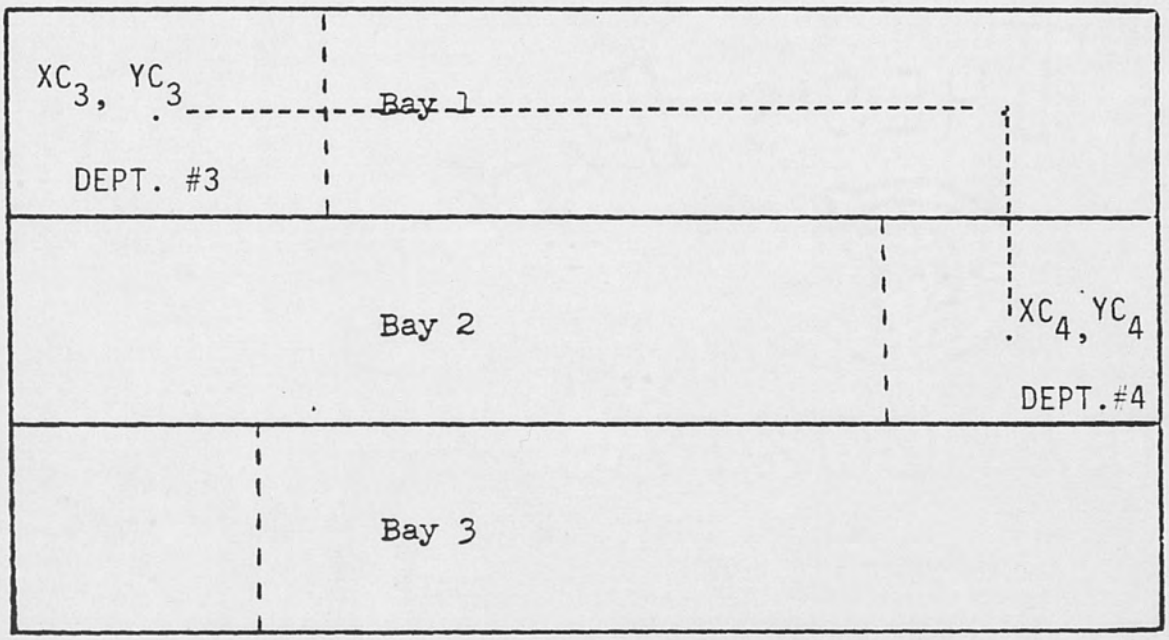


Figure 3.4. Rectilinear distance from department #3 to department #4.

$$RD = | X C_4 - XC_3 | + | YC_4 - YC_3 |$$

Algorithm and Logic

Based on the dimensions of the plant area, number of bays desired, department-sequence, and department areas, the bay arrangement, (statement # 395 in program listing), arranges the departments in the plant bays and computes the coordinates of the centers. The algorithm starts the arrangement in the "Northwest" corner of the rectangular area and positions the first department in the sequence into that position. This process continues until the bay is filled [4]. A department might be located in two bays. This situation occurs when locating a department in a bay where it can only be partially accomodated. The routine continues locating the rest of the department in the next bay, i.e., the departmental areas are honored.

The coordinates of each department in the layout are determined by the XY-coordinates subroutine. The departments are all rectangular, except those departments which occupy more than one bay. The coordinates key is shown in Figure 3.1. The routine calculates the minimum rectlinear distances between the departments centers. If a department occupies more than one bay, the X_c coordinate is located in the bay where the largest area of the department exists.*
A list of the bays, their contents, and departments coordinates are produced as a result of this routine.

---

* A relative approximation of the program which is debatable in practical cases.

Total cost of material movement between all departments is then computed and retained. A pairwise exchange routine then exchanges each department location with the other departments and cycles through the coordinates and distance routines, computing the total cost of material handling each time. If there is an improvement, the program implements the exchange. The program considers the arrangement "in hand" as an initial layout, repeats from the begining the program steps, and reports the location of each department expressed as corner coordinates and the total cost of material handling according to this arrangement. The exchange routine is active until there are no more improvements or all exchanges have taken place.

a = given assignment
D = distance matrix
W = weight matrix
TC(a) = total cost of given assignment
e = maximum of 0, the greatest decrease in TC(a)
DTC = difference in total costs of two arrangements

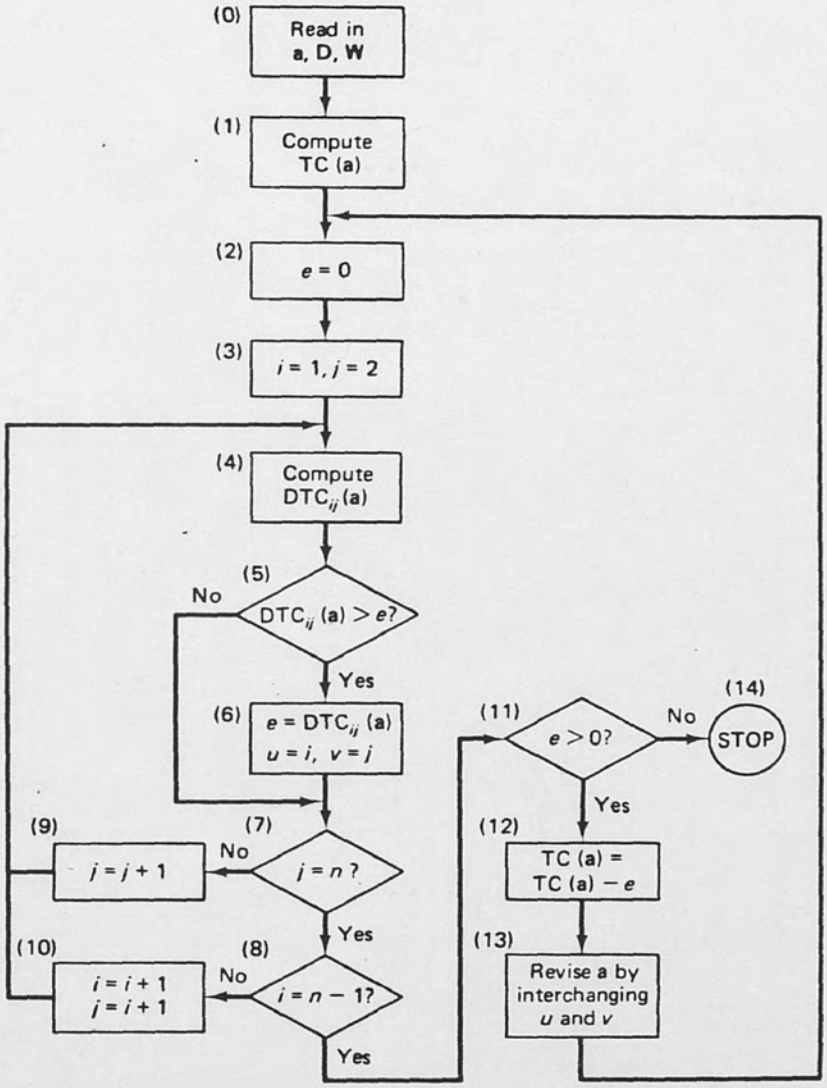


Figure 3.5. Flow chart of steepest - descent pairwise-interchange procedure.

Program Documentation

Program Name: CRAFT (Computerized Relative Allocation of Facilities Technique).

Program Function: CRAFT is layout improvement program that seeks a sub-optimal department arrangement with respect to cost of material.

Program Input:

1. Number of production departments.
2. Number of trips between departments.
3. Cost per trip a unit distance.
4. Length of available area.
5. Width of available area.
6. Number of bays.
7. For a given sequence, the department number and corresponding area.

Program Logic:

1. Accept input (# of trips between departments and cost per trip a unit distance, length and width of available area, # of bays desired).
2. Display data, accept corrections if any, if not, continue.
3. Space available is computed.

   Space available = length * width of available area.

4. Bay span is computed.

   Bay span = width of available area/# bays.

5. For a given sequence, department number and area are entered.
6. Make corrections, if any, if not, continue.
7. XY - coordinates are computed (statement # 880 in program listing).

8. Rectilinear distances between each department are computed using the centroids of each department.

9. Total handling cost is computed.

   Matrix C_{ij} = cost to move the total product flow between departments for a unit distance.

   Matrix D_{ij} = distances between departmental centers.

   Total cost = $\Sigma\Sigma\ C_{ij}\ D_{ij}$

10. Compare this total handling cost with the previous value. If the new value is less than the previous one, implement the exchange and begin exchange subroutine again.

11. Exchange subroutine uses pairwise exchange routine as its basic technique and cycles to step #7. The exchange process continues until no improvement can be made.

12. Final, improved layout arrangement is computed and displayed.

13. XY - coordinates are displayed.

14. Rectlinear distances between each department are displayed.

15. Improved handling cost is computed and displayed.

16. Exit program.

Program Output: Improved layout arrangement, XY - coordinates given as the corner coordinates of each department, distance matrix, and handling cost. (Refer to case example).

Program Listing

```
10  REM  **PLANT LAYOUT-FROM/TO C
    HART
15  GOSUB 60
20  CLEAR
25 Z% = 0
30  PRINT : PRINT : PRINT
35  PRINT
40  INPUT "ENTER # OF PRODUCTION
    DEPARTMENTS ";ND
45  DIM DD(ND,ND),CS(ND,ND),CT(ND
    ,ND)
50  GOTO 105
55  HOME
60  HOME : FOR X = 1 TO 5: PRINT
    : NEXT X
65  PRINT "              PLANT DESI
    GN"
70  PRINT "                 CRAFT"
75  PRINT
80  PRINT "             IEMS DEPART
    MENT"
85  PRINT "     UNIVERSITY OF CEN
    TRAL FLORIDA"
90  FOR X = 1 TO 3000: NEXT X: HOME

95  RETURN
100  STOP
105  HOME : PRINT : PRINT : PRINT

110  PRINT "INPUT # TRIPS BETWEEN
     DEPARTMENTS"
115  PRINT "AND COST PER TRIP A U
     NIT DISTANCE": PRINT : PRINT

120  FOR I = 1 TO ND
125  PRINT "FROM DEPT. ";I
130  FOR J = 1 TO ND
135  IF J = I THEN  GOTO 190
140  PRINT "       TO DEPT. ";J;"
     #TRIPS,COST = ";: INPUT DD(
     I,J),CS(I,J)
145 IC = IC + 1
150  IF IC < 12 THEN 190'
155  GOSUB 240
160  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE::GET Y$
```

```
165 IC = 0
170 JR = ND - 1
175  IF I = ND AND J = JR GOTO 20
    5
180  IF J = ND THEN  HOME : GOTO
    190
185  HOME : PRINT "FROM DEPT. ";I

190  NEXT J
195  NEXT I
200  GOSUB 240
205  HOME : PRINT : PRINT
210  FOR I = 1 TO ND
215  FOR J = 1 TO ND
220 CT(I,J) = CS(I,J) * DD(I,J)
225  NEXT J
230  NEXT I
235  GOTO 295
240  INPUT "DO YOU WANT TO MAKE C
    HANGES (Y OR N) ";Y$
245  IF Y$ = "Y" GOTO 260
250  IF Y$ = "N" GOTO 285
255  GOTO 240
260  HOME : PRINT : PRINT
265  INPUT "CHANGE DATA FROM DEPT
    . ";I1
270  INPUT "                TO DEPT
    . ";J1
275  INPUT "          # TRIPS,COST
      ";DD(I1,J1),CS(I1,J1)
280  PRINT : PRINT "** CHANGE IMP
    LEMENTED **": GOTO 240
285  HOME
290  RETURN
295  REM  ** CRAFT **
300  FOR X = 1 TO 4: PRINT : NEXT
    X
305  INPUT "ENTER LENGTH OF AVAIL
    ABLE AREA  ";BL: PRINT
310  INPUT "ENTER WIDTH OF AVAILA
    BLE AREA  ";BW: PRINT
315  PRINT "**********************
    ********************"
320 Z = BL * BW: PRINT "TOTAL SPA
    CE AVAILABLE = ";Z;" SQ.UNIT
    S"
325  PRINT "**********************
    ********************": PRINT
```

```
330  INPUT "ENTER # OF BAYS DESIR
     ED ";NB
335  PRINT
340  PRINT "**********************
     ********************"
345 BS = BW / NB
350  PRINT "BAY SPAN = ";BS
355  PRINT "**********************
     ********************": PRINT :
      PRINT
360  PRINT "HIT RETURN TO CONTINU
     E ";: GET Y$
365  DIM BAC(NB),BL(NB,25),B(25,2
     5)
370  DIM X1(NB,25),Y1(NB,25),X2(N
     B,25),Y2(NB,25),XC(25,25),YC
     (25,25)
375  DIM DA(50),DN(50),DL(50),DB(
     25),FG(10),FB(10)
380  IF JP = 1 GOTO 420
385  HOME
386  FOR X = 1 TO 5: PRINT : NEXT
     X
390 BB = 0
395  PRINT "**********************
     ********************"
400  PRINT "ARRANGEMENT BEGINS IN
      NORTHWEST": PRINT "CORNER O
     F RECTANGULAR AREA."
405  PRINT "FOR THE FOLLOWING SEQ
     UENCE"
410  PRINT "ENTER :  DEPT.#,AREA
415  PRINT "**********************
     ********************"
420 R1 = 0:R2 = 0:D1 = 0:F = 1:S =
     0:BB = 0
425  FOR I = 1 TO NB:BAC(I) = 0: NEXT
     I
430  FOR I = 1 TO NB:DB(I) = 0: NEXT
     I
435 TT = 0
440  FOR I = 1 TO NB:FG(I) = 0: NEXT
     I
442  IF AG = 77 GOTO 465
445  IF JP = 0 GOTO 455
450  IF JP = 1 GOTO 465
455  PRINT "SEQUENCE  DEPT.#,AREA
     "
```

```
460  PRINT "--------------------"

465  FOR I = 1 TO NB
470 R1 = 0:D1 = 0
475  FOR J = F TO ND
480 BB = BB + 1
485  IF JP = 1 GOTO 505
486  IF AG = 77 GOTO 505
490  PRINT "    ";BB;" INPUT "
          ";DN(J),DA(J)
495  IF JP = 0 GOTO 505
505 TT = TT + DA(J)
510  IF TT > Z GOTO 820
515 S = S + 1
520 DL(J) = DA(J) / BS
525 BAC(I) = BAC(I) + DL(J)
530  IF BAC(I) < BL GOTO 545
535  IF BAC(I) = BL GOTO 585
540  IF BAC(I) > BL GOTO 625
545 R1 = BL - BAC(I)
550  IF R1 < 10 GOTO 570
555 BL(I,S) = DL(J)
560 B(I,S) = DN(J)
565  GOTO 580
570 DL(J) = DL(J) + R1
575  GOTO 585
580  NEXT J
585 BL(I,S) = DL(J)
590 B(I,S) = DN(J)
595 DB(I) = J - F + 1
600  IF FG(I) = 1 THEN DB(I) = DB
     (I) + 1
605 F = J + 1
610 FB = 0
615 S = 0
620  GOTO 720
625 R1 = BAC(I) - BL
630  IF R1 < 10 GOTO 710
635 R2 = DL(J) - R1
640 BL(I,S) = R2
645 B(I,S) = DN(J)
650 FB(I) = 1
655 DB(I) = J - F + 1
660  IF FG(I) = 1 THEN DB(I) = DB
     (I) + 1
665 M = I + 1
670 FG(M) = 1
```

```
675 D1 = DN(J)
680 BAC(M) = BAC(M) + R1
685 BL(M,1) = R1
690 B(M,1) = D1
695 S = 1
700 F = J + 1
705  GOTO 720
710 DL(J) = DL(J) - R1
715  GOTO 585
720  NEXT I
722  IF JP = 1 GOTO 745
723  IF AG = 77 GOTO 740
725  PRINT : PRINT
730  INPUT "DO YOU WANT TO MAKE C
     HANGES, YES OR NO?   ";A3$
735  IF A3$ = "YES" THEN  GOTO 84
     0
736  IF AG = 77 GOTO 420
740  HOME
745  FOR I = 1 TO NB
750  IF BL(I,1) = 0 GOTO 760
755  GOTO 810
760 J1 = DB(I)
765 J1 = J1 - 1
770  FOR J = 1 TO J1
775 J2 = J + 1
780 BL(I,J) = BL(I,J2)
785 B(I,J) = B(I,J2)
790  NEXT J
795 DB(I) = DB(I) - 1
800 M = I - 1
805 DB(M) = DB(M) - 1
810  NEXT I
812  IF JP = 1 GOTO 905
815  GOTO 875
820  PRINT : PRINT : PRINT "*****
     **************************
     *****"
825  PRINT "THE TOTAL AVAILABLE S
     PACE REQUIREMENTS": PRINT "H
     AVE BEEN EXCEEDED BY ";TT -
     Z;" SQ.UNITS
830  PRINT "**********************
     ******************": PRINT
835  END
840  HOME : PRINT : PRINT : PRINT
     : INPUT "ENTER SEQUENCE # OF
      DEPT. TO BE CHANGED ";A1
```

```
845  PRINT : PRINT "ENTER DEPT.#,
     AREA TO BE CHANGED ": PRINT

850  INPUT "          ";DN(A1),DA(
     A1)
855  PRINT : PRINT "** CHANGE IMP
     LEMENTED **": PRINT
856 AG = 77
857  GOTO 725
860  HOME : FOR X = 1 TO 8: PRINT
     : NEXT X
865  PRINT "       EXCHANGE SUBROU
     TINE": PRINT : PRINT : PRINT

870  PRINT "         PLEASE STAND
     BY"
875  HOME : PRINT : PRINT : PRINT
     : PRINT
880  PRINT "       SUBROUTINE CALC
     ULATING"
885  PRINT
890  PRINT "          XY-COORDINAT
     ES"
895  FOR X = 1 TO 3000: NEXT X
900  HOME
905  FOR I = 1 TO NB
910  IF I = 1 GOTO 935
915  IF I = 3 GOTO 935
920 F = I / 2
925 F = F * 2
930  IF F = I GOTO 985
935 X1(I,1) = 0
940 N1 = DB(I)
945 XC(I,1) = BL(I,1) / 2
950  FOR J = 1 TO N1
955 X2(I,J) = X1(I,J) + BL(I,J)
960 J1 = J + 1
965  IF J = N1 GOTO 975
970 X1(I,J1) = X2(I,J)
975  NEXT J
980  GOTO 1030
985 N1 = DB(I)
990 X2(I,1) = BL
995  FOR J3 = 1 TO N1
1000 X1(I,J3) = X2(I,J3) - BL(I,J
     3)
1005 J2 = J - 1
```

```
1010 J4 = J3 + 1
1015  IF J3 = N1 GOTO 1025
1020 X2(I,J4) = X1(I,J3)
1025  NEXT J3
1030  NEXT I
1035 Y1(1,1) = BW
1040  FOR I = 1 TO NB
1045 N1 = DB(I)
1050  FOR J = 1 TO N1
1055 Y1(I,J) = Y1(I,1)
1060 Y2(I,J) = Y1(I,J) - BS
1065  NEXT J
1070  IF I = NB GOTO 1085
1075 I2 = I + 1
1080 Y1(I2,1) = Y2(I,1)
1085  NEXT I
1090  FOR I = 1 TO NB
1095 J2 = DB(I)
1100  FOR J = 1 TO J2
1105 XC(I,J) = (X1(I,J) + ((BL(I,
     J)) / 2.0))
1110  NEXT J
1115  NEXT I
1120 HALF = 0.5 * BS
1125 YC(1,1) = Y1(1,1) - HALF
1130 J6 = DB(I)
1135  FOR J = 1 TO J6
1140 YC(1,J) = YC(1,1)
1145  NEXT J
1150  FOR I = 2 TO NB
1155 J6 = DB(I)
1160  FOR J = 1 TO J6
1165 I2 = I - 1
1170 YC(I,J) = YC(I2,1) - BS
1175  NEXT J
1180  NEXT I
1182  IF JP = 1 GOTO 1210
1185  HOME : PRINT : PRINT
1190  PRINT "      XY-COORDINATES
     CHART"
1195  PRINT "    ----------------
     ------": PRINT : PRINT
1200  PRINT "SEQ ";"DEP ";"X1    "
     ;"Y1    ";"X2    ";"Y2    ";"XC
        ";"YC"
1205  PRINT "--------------------
     --------------------"
1210 BB = 0
```

```
1215  FOR I = 1 TO NB
1220 J1 = DB(I)
1225  FOR J = 1 TO J1
1230 BB = BB + 1
1235 Y1(I,J) =  ABS (Y1(I,J) - BW
     )
1240 Y2(I,J) =  ABS (Y2(I,J) - BW
     )
1245 YC(I,J) =  ABS (YC(I,J) - BW
     )
1250 YC(1,J) = YC(1,1)
1252  IF JP = 1 GOTO 1260
1255  PRINT " ";BB;"    ";B(I,J); TAB(
     9);X1(I,J); TAB( 14);Y1(I,J)
     ; TAB( 19);X2(I,J); TAB( 24)
     ;Y2(I,J); TAB( 29);XC(I,J); TAB(
     34);YC(I,J)
1260  NEXT J
1265  NEXT I
1270  FOR I = 1 TO NB
1275 J1 = DB(I)
1280 M = I + 1
1285  IF M > NB AND JP = 1 GOTO 1
     370
1290  IF B(I,J1) = B(M,1) THEN  GOTO
     1305
1295  NEXT I
1297  IF JP = 1 GOTO 1370
1300  GOTO 1360
1305 M = 0
1310  FOR I = 1 TO NB
1315 J1 = DB(I)
1320 M = I + 1
1322  IF M > NB AND JP = 1 GOTO 1
     370
1325  IF M > NB GOTO 1360
1330  IF BL(I,J1) > BL(M,1) GOTO
     1345
1335 XC(I,J1) = XC(M,1);YC(I,J1) =
     YC(M,1)
1340  GOTO 1350
1345 XC(M,1) = XC(I,J1);YC(M,1) =
     YC(I,J1)
1350  NEXT I
1355  GOTO 1295
1356  IF JP = 1 GOTO 1370
1360  PRINT : PRINT "HIT 'RETURN'
      TO CONTINUE ";: GET Y$
```

```
1365  HOME
1370  FOR I = 1 TO ND
1375  FOR J = 1 TO ND
1380 DS(I,J) = 99999
1385  NEXT J
1390  NEXT I
1395  FOR I = 1 TO NB
1400 J2 = DB(I)
1405  FOR J = 1 TO J2
1410  FOR I1 = 1 TO NB
1415 J3 = DB(I)
1420  FOR J1 = 1 TO J3
1425 J5 = B(I,J)
1430 J4 = B(I1,J1)
1435 D1 =  ABS (XC(I,J) - XC(I1,J
     1))
1440 D1 = D1 +  ABS (YC(I,J) - YC
     (I1,J1))
1445  IF D1 <  = DS(J5,J4) THEN D
     S(J5,J4) = D1
1450  NEXT J1
1455  NEXT I1
1460  NEXT J
1465  NEXT I
1466  IF JP = 1 GOTO 1480
1470  PRINT : PRINT "   DISTANCE
     MATRIX"
1475  PRINT "  ------------------"

1480 J = 0
1485  FOR F = 1 TO ND
1490  FOR F1 = 1 TO ND
1495  IF DS(F,F1) < DS(F1,F) THEN
     DS(F1,F) = DS(F,F1)
1500  IF DS(F1,F) < DS(F,F1) THEN
     DS(F,F1) = DS(F1,F)
1505 J = J + 1
1510 A = A + 5
1512  IF JP = 1 GOTO 1519
1515  PRINT DS(F,F1); TAB( A);
1519  IF J = ND AND JP = 1 THEN J
     = 0: GOTO 1525
1520  IF J = ND THEN J = 0: PRINT

1525  NEXT F1
1530 A = 0
1535  NEXT F
1540  REM  ** TOTAL HANDLING COST
      **
```

```
1545  IF JP = 1 GOTO 1590
1550 TC = 0
1555  FOR I = 1 TO ND
1560  FOR J = 1 TO ND
1565 CST = DS(I,J) * CT(I,J)
1570 TC = TC + CST
1575  NEXT J
1580  NEXT I
1585  IF JP = 0 GOTO 1650
1590 T1 = 0
1595  FOR I = 1 TO ND
1600  FOR J = 1 TO ND
1605 CST = DS(I,J) * CT(I,J)
1610 T1 = T1 + CST
1615  NEXT J
1620  NEXT I
1630  IF U = 7 THEN  RETURN
1635  IF TC <  = T1 THEN  RETURN

1640  IF T1 < TC THEN TC = T1:V =
      0:PP = 77
1645  RETURN
1650  PRINT : PRINT : PRINT
1655  PRINT "----------------------
      ----------------"
1660  PRINT "TOTAL HANDLING COST
      = ";TC
1665  PRINT "----------------------
      ----------------"
1670  PRINT "HIT 'RETURN' TO CONT
      INUE ";: GET Y$
1675  HOME
1680 PP = 0
1685 E = 1
1690 G = 0
1695 Q = ND - 1
1700  FOR G = 1 TO Q
1705 J1 = G + 1
1710 EN = DN(E)
1715 EA = DA(E)
1720 DN(E) = DN(J1)
1725 DA(E) = DA(J1)
1730 DN(J1) = EN
1735 DA(J1) = EA
1736  IF JP = 1 GOTO 1740
1737  FOR I = 1 TO 5: PRINT : NEXT
      I
```

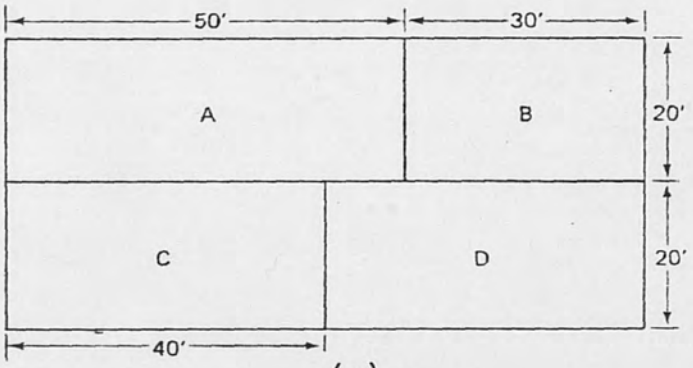
```
1738  PRINT "       EXCHANGE SUBRO
      UTINE"
1739  PRINT : PRINT : PRINT "
         PLEASE STAND BY"
1740 JP = 1
1745 V = V + 1
1750  GOSUB 380
1752  IF JP = 1 GOTO 1760
1755  PRINT : PRINT "HIT 'RETURN'
      TO CONTINUE ";: GET Y$
1760  IF PP = 77 GOTO 1680
1765 J1 = G + 1
1770 EN = DN(E)
1775 EA = DA(E)
1780 DN(E) = DN(J1)
1785 DA(E) = DA(J1)
1790 DN(J1) = EN
1795 DA(J1) = EA
1800 U = 7
1805  GOSUB 380
1810 U = 0
1815  NEXT G
1820  HOME
1825  FOR I = 1 TO 4: PRINT : NEXT
      I
1830  PRINT "**********************
      ****************"
1835  PRINT "           FINAL ARRA
      NGEMENT"
1840  PRINT "**********************
      ****************"
1845 BB = 0
1850  PRINT "SEQUENCE    DEPT.#,AR
      EA"
1855  PRINT "--------------------
      ----": PRINT
1860  FOR J = 1 TO ND
1865 BB = BB + 1
1870  PRINT "     ";BB;"          ";
      DN(J),DA(J)
1875  NEXT J
1880  PRINT : PRINT "HIT 'RETURN'
      TO CONTINUE ";: GET Y$
1885  HOME : FOR I = 1 TO 5: PRINT
      : NEXT I
1890  PRINT "     XY-COORDINATES C
      HART"
```

```
1895  PRINT "--------------------
      ----------": PRINT : PRINT

1900  PRINT "SEQ ";"DEP ";"X1    "
      ;"Y1    ";"X2    ";"Y2    ";"XC
         ";"YC"
1905  PRINT "--------------------
      ------------------"
1910 BB = 0
1915  FOR I = 1 TO NB
1920 J1 = DB(I)
1925  FOR J = 1 TO J1
1930 BB = BB + 1
1935  PRINT " ";BB;"    ";B(I,J); TAB(
      9);X1(I,J); TAB( 14);Y1(I,J)
      ; TAB( 19);X2(I,J); TAB( 24)
      ;Y2(I,J); TAB( 29);XC(I,J); TAB(
      34);YC(I,J)
1940  NEXT J
1945  NEXT I
1950  PRINT : PRINT "HIT 'RETURN'
      TO CONTINUE";: GET Y$
1955  HOME : PRINT : PRINT
1960  PRINT "          DISTANCE MA
      TRIX"
1965  PRINT "--------------------
      ---------------"
1970 J = 0
1975  FOR F = 1 TO ND
1980  FOR F1 = 1 TO ND
1985  IF DS(F,F1) < DS(F1,F) THEN
      DS(F1,F) = DS(F,F1)
1990  IF DS(F1,F) < DS(F,F1) THEN
      DS(F,F1) = DS(F1,F)
1995 J = J + 1
2000 A = A + 5
2005  PRINT DS(F,F1); TAB( A)
2010  IF J = ND THEN J = 0: PRINT

2015  NEXT F1
2020 A = 0
2025  NEXT F
2030  PRINT : PRINT
2035  PRINT "--------------------
      ---------------"
```

```
2040  PRINT "TOTAL HANDLING COST
     = ";TC
2045  PRINT "--------------------
     ----------------"
2050  PRINT : PRINT "HIT 'RETURN'
      TO CONTINUE";: GET Y$
2055  HOME : PRINT : PRINT : PRINT
     : PRINT "NEXT STEP TO BE PER
     FORMED"
2060  PRINT "      1.EXIT PROGRAM"

2065  PRINT "      2.INPUT NEW DAT
     A"
2070  PRINT : PRINT : PRINT "ENTE
     R CHOICE # ": GET X
2075  ON X GOTO 2080,10
2080  END
```

Case Example

To illustrate the approach used by CRAFT to develop layouts, consider the initial layout and the From/To Chart for the flow data given in Figure 3.6 [4]. For simplicity it will be assumed all cost elements are equal to unity in the From/To Chart for the cost data.



(a)

From \ To	1	2	3	4
1	0	2	4	4
2	1	0	1	3
3	2	1	0	2
4	4	1	0	0

(b)

From \ To	1	2	3	4
1	0	40	25	55
2	40	0	65	25
3	25	65	0	40
4	55	25	40	0

(c)

Figure 3.6. a) Initial layout, b) flow data, c) distance data.

After loading the program and typing RUN, the screen displays the following:

```
PLANT DESIGN
CRAFT

ICMS DEPARTMENT
UNIVERSITY OF CENTRAL FLORIDA
```

This case example involves four production departments. The program begins with the following questions:

```
ENTER # OF PRODUCTION DEPARTMENTS 4


INPUT # TRIPS BETWEEN DEPARTMENTS
AND COST PER TRIP A UNIT DISTANCE


FROM DEPT. 1
      TO DEPT. 2  #TRIPS,COST = ?2,1
      TO DEPT. 3  #TRIPS,COST = ?4,1
      TO DEPT. 4  #TRIPS,COST = ?4,1
FROM DEPT. 2
      TO DEPT. 1  #TRIPS,COST = ?1,1
      TO DEPT. 3  #TRIPS,COST = ?1,1
      TO DEPT. 4  #TRIPS,COST = ?3,1
FROM DEPT. 3
      TO DEPT. 1  #TRIPS,COST = ?2,1
      TO DEPT. 2  #TRIPS,COST = ?1,1
      TO DEPT. 4  #TRIPS,COST = ?2,1
FROM DEPT. 4
      TO DEPT. 1  #TRIPS,COST = ?4,1
      TO DEPT. 2  #TRIPS,COST = ?1,1
      TO DEPT. 3  #TRIPS,COST = ?0,1
DO YOU WANT TO MAKE CHANGES (Y OR N) Y
```

The opportunity to make corrections is given after entering the required data. Corrections are made with the format From Dept., To Dept., and the corrected # trips, cost.

```
CHANGE DATA FROM DEPT. 4
               TO DEPT. 1
          # TRIPS,COST  4,1

** CHANGE IMPLEMENTED **
DO YOU WANT TO MAKE CHANGES (Y OR N)
DO YOU WANT TO MAKE CHANGES (Y OR N) N

HIT 'RETURN' TO CONTINUE;↓GET Y$
```

The required data pertinent to the layout arrangement is now entered.

```
ENTER LENGTH OF AVAILABLE AREA  80

ENTER WIDTH OF AVAILABLE AREA  40
```

The space available is computed.

```
**********************************************
TOTAL SPACE AVAILABLE = 3200 SQ.UNITS
**********************************************
```

The number of bays desired in the layout arrangement is now entered.

```
ENTER # OF BAYS DESIRED 2
```

The bay span is now computed.

```
**********************************************
BAY SPAN = 20
**********************************************

HIT RETURN TO CONTINUE
```

The department number and area are now entered for a given initial sequence.

```
**********************************************
ARRANGEMENT BEGINS IN NORTHWEST
CORNER OF RECTANGULAR AREA.
FOR THE FOLLOWING SEQUENCE
ENTER :  DEPT.#,AREA
**********************************************
SEQUENCE   DEPT.#,AREA
--------   -----------
    1         1,1000
    2         2,600
    3         4,800
    4         3,800

DO YOU WANT TO MAKE CHANGES, YES OR NO?   NO
```

The opportunity to make corrections is given after entering the required data.

While the computer is calculating the XY - Coordinates, the program will display

SUBROUTINE CALCULATING

XY-COORDINATES

for the period in which computation is taking place. The results are then displayed to the user.

XY-COORDINATES CHART

SEQ	DEP	X1	Y1	X2	Y2	XC	YC
1	1	0	0	50	20	25	10
2	2	50	0	80	20	65	10
3	4	40	20	80	40	60	30
4	3	0	20	40	40	20	30

HIT 'RETURN' TO CONTINUE

The rectilinear distances between each department and the handling cost are now computed and displayed.

DISTANCE MATRIX

0	40	25	55
40	0	65	25
25	65	0	40
55	25	40	0

TOTAL HANDLING COST = 1020

HIT 'RETURN' TO CONTINUE

While the computer is performing pairwise exchange, the program will display

```
EXCHANGE SUBROUTINE

PLEASE STAND BY
```

for the period in which exchanges are being made. The final layout arrangement is then displayed to the user (sequence, areas, coordinates for the 4 corners of each department and rectilinear distance).

```
**********************************
          FINAL ARRANGEMENT
**********************************
SEQUENCE    DEPT.#,AREA
----------------------------------

     1          4   800
     2          2   600
     3          3   800
     4          1   1000

HIT 'RETURN' TO CONTINUE
```

XY-COORDINATES CHART

SEQ	DEP	X1	Y1	X2	Y2	XC	YC
1	4	0	0	40	20	20	10
2	2	40	0	70	20	55	10
3	3	70	0	80	20	65	30
4	3	50	20	80	40	65	30
5	1	0	20	50	40	25	30

HIT 'RETURN' TO CONTINUE

DISTANCE MATRIX

0	50	40	25
50	0	30	35
40	30	0	65
25	35	65	0

TOTAL HANDLING COST = 920

HIT 'RETURN' TO CONTINUE

Finally, program options are now displayed.

```
NEXT STEP TO BE PERFORMED
     1.EXIT PROGRAM
     2.INPUT NEW DATA

ENTER CHOICE #
```

CHAPTER IV

REL CHART

Introduction

Flow analysis tends to relate various activities on a quantitative basis. The relationship is normally expressed as some function of material-handling cost. However, a number of factors other than material-handling cost might be of primary concern in layout design. The activity relationship chart, also referred to as the REL chart was designed to facilitate a consideration of qualitative factors. The REL chart, as developed by Muther [7], replaces the quantitative data in a From/To chart by qualitative closeness ratings.

It is the purpose of this section to present a computer program written in Interactive Basic, which builds a REL Chart equivalent to quantitative material flow expressed in number of trips (Chapter II). The produced REL Chart reflects production requirements expressed in closeness ratings as follows:

Relationship	Closeness Rating*	and their program numerical values
Absolutely necessary	A	6
Especially important	E	5
Important	I	4
Ordinary closeness	O	3
Unimportant	U	2
Undesireable	X	1

The user must supply the extreme values for the "Absolutely Necessary" relationship and the "Undesireable" relationship if pertinent*.

The creation of the product equivalent relationship chart between the production departments is generated by using product data. Based on each products sequence of operations, the moving batch size, and the quantities to be produced, a From/To Chart is constructed (refer to Chapter II). The highest value and the lowest value of the number of trips in the From/To Chart are determined. The difference between highest and lowest value is divided into four spans, and a highest value and lowest value of each category are determined. These categories correspond to the A, E, I, O, and U closeness ratings. Each entry within the From/To table is evaluated, and the corresponding closeness rating is assigned. Closeness ratings A and X are to be assigned by the user depending on product design and processes.

If data concerns the cost per trip between various departments, the user might include the effect of varying costs by adjusting the "quantity" value accepted as part of the input data required.

---

* Ratings are commonly used by layout designer.

Program Documentation

Program Name: Product REL Chart.

Program Function: The Product REL Chart provides a representation of a measure of activity relationships by performing pairwise evaluations of the importance for two activities to be located together in the layout.

Program Input:

1. Number of parts to be produced.
2. Number of production departments.
3. The quantity associated for each part.
4. The batch size associated for each part.
5. The sequence of operations associated for each part.

Program Logic:

1. Accept input.
2. Display data, make corrections if any, if not, continue.
3. Relationship chart with respect to the product is formed.
   - From/To Chart is constructed (Refer to Chapter II).
   - Four spans are computed, corresponding to the E, I, O, U Closeness ratings*.

     Span = (Highest # trips - Lowest # trips)/4
   - A highest value and lowest value for each category are determined.
   - Each entry within the From/To Chart is evaluated and assigned the corresponding closeness rating.

Program Output: Relationship Chart with respect to the product.

---

* Closeness ratings A and X are to be assigned by the user.

Program Listing

```
10  REM  **PLANT LAYOUT-DEPARTMEN
     TAL RELATIONSHIP CHART
15  GOSUB 645
20  CLEAR
25  PRINT : PRINT : PRINT
30  INPUT "ENTER # OF PARTS TO BE
      PRODUCED ";NP
35  PRINT
40  DIM P(NP,50),Q(NP),B(NP),TP(N
     P),N(NP)
45  INPUT "ENTER # OF PRODUCTION
     DEPARTMENTS ";ND
50  DIM DD(ND,ND)
55  PRINT
60  HOME
65  PRINT "FOR EACH PART ENTER:"
70  PRINT : PRINT "     QUANTITY,
     BATCH SIZE,SEQUENCE"
75  PRINT "      OF OPERATIONS"
80  PRINT : PRINT "NOTE:": PRINT

85  PRINT "    1- USE DEPT.#'S FO
     R OPERATIONS": PRINT
90  PRINT "    2- USED DEPT.#'S C
     AN NOT EXCEED ";ND
95  PRINT
100  PRINT "    3- ENTER '0' TO E
     ND OPERATIONAL SEQ."
105  PRINT : PRINT "    4- # OF O
     PERATIONS CAN NOT EXCEED": PRINT
     "        50 PER PART "
110  PRINT : PRINT : PRINT : PRINT

115  PRINT : PRINT : INPUT "HIT R
     ETURN WHEN READY ";Y$
120  HOME
125  FOR J = 1 TO NP
130  GOSUB 135: GOTO 225
135 N(J) = 0
140  PRINT "PART # ";J
145  INPUT "ENTER QUANTITY ";Q(J)

150  INPUT "ENTER,BATCH SIZE ";B(
     J)
155  IF B(J) = 0 THEN  PRINT "BAT
     CH SIZE CAN NOT BE 0, REENTE
     R": GOTO 150
160  FOR I = 1 TO 50
```

```
165  PRINT "ENTER DEPT.# FOR OPER
     ATION ";I;
170  INPUT " : ";P(J,I)
175  IF P(J,I) > ND THEN  PRINT "
     DEPARTMENT # EXCEEDS THE # O
     F DEPTS.": PRINT "REENTER": GOTO
     165
180  IF I > 1 THEN I1 = I - 1: IF
     P(J,I) = P(J,I1) THEN  PRINT
     "TRIPS CANNOT BE INSIDE SAME
      DEPARTMENT": PRINT "REENTER
     ": GOTO 165
185  IF P(J,I) = 0 THEN 205
190 N(J) = N(J) + 1
195  NEXT I
200  PRINT : PRINT
205  PRINT : INPUT "DO YOU WANT T
     O MAKE CHANGES, (Y OR N)?";B
     $: IF B$ = "N" THEN 220
210  GOSUB 695
215  GOTO 205
220  RETURN
225  HOME
230  NEXT J
235  REM ** #TRIPS BETWEEN DEPTS
     ARE CALCULATED
240  PRINT : PRINT : PRINT
245  PRINT "   YOUR COMPUTER IS C
     ALCULATING": PRINT "       P
     LEASE STAND BY"
250  FOR J = 1 TO NP
255 T = Q(J) / B(J):I% = T:R = T -
     I%
260  IF R = 0 THEN TP(J) = T: GOTO
     270
265 TP(J) = I% + 1
270  NEXT J
275  FOR J = 1 TO NP
280 M = N(J) - 1
285  FOR I = 1 TO M
290 I1 = I + 1
295 J1 = P(J,I):J2 = P(J,I1)
300 DD(J1,J2) = DD(J1,J2) + TP(J)

305  NEXT I
310  NEXT J
315  FOR I = 1 TO ND
320  FOR J = 1 TO ND
325 DD(I,J) = DD(I,J) + DD(J,I)
```

```
330 DD(J,I) = DD(I,J)
335  NEXT J
340  NEXT I
345  REM  **GENERATE REL CHART
350 MIN = 9999:MAX = 0
355  FOR I = 1 TO ND
360  FOR J = 1 TO ND
365  IF DD(I,J) > MAX THEN MAX =
     DD(I,J)
370  IF (DD(I,J) < MIN) THEN MIN =
     DD(I,J)
375  NEXT J
380  NEXT I
385 S = (MAX - MIN) / 4
390 IC = 0
395  FOR I = 1 TO ND
400  FOR J = 1 TO ND
405  FOR I1 = 1 TO 4
410  IF DD(I,J) <  = (I1 * S - MI
     N) THEN DD(I,J) = I1 + 1: GOTO
     420
415  NEXT I1
420  NEXT J
425  NEXT I
430  FOR I = 1 TO ND
435  FOR J = 1 TO ND
440  IF I = J THEN DD(I,J) = 0: GOTO
     455
445  IF DD(I,J) > DD(J,I) THEN DD
     (J,I) = DD(I,J): GOTO 455
450  IF DD(J,I) > DD(I,J) THEN DD
     (I,J) = DD(J,I)
455  NEXT J
460  NEXT I
465  HOME
470  FOR RT = 1 TO 3: PRINT : NEXT
     RT
475  PRINT "NOTE:": PRINT : PRINT
     " -THE USER MAY SUPPLY CERTA
     IN RELVALS": PRINT "  WHICH
     WILL AUTOMATICALLY OVERRIDE"
     : PRINT "  THE GENERATED VAL
     UES": PRINT : PRINT
480  PRINT " -RELVAL NO.1 AND NO.
     6 MUST BE SUPPLIED": PRINT "
       BY THE USER IF PERTINENT":
      PRINT : PRINT
485  PRINT "  DO YOU WANT TO SUPP
     LY ANY RELVALS ?": PRINT : INPUT
     "  (Y OR N)  ";Y$
```

```
490  IF Y$ = "Y" THEN  GOSUB 815:
      GOTO 505
495  IF Y$ = "N" THEN 505
500  GOTO 485
505  HOME : GOSUB 510: GOTO 595
510  PRINT "   DEPARTMENAL RELATI
     ONSHIP CHART": PRINT "   ---
     ----------------------------
     ": PRINT
515  FOR I = 1 TO ND
520  PRINT "BETWEEN DEPT. ";I
525  FOR J = 1 TO ND
530  PRINT "          AND DEPT. ";
     J;" RELVAL= ";DD(I,J)
535 IC = IC + 1
540  IF IC < 9 THEN 570
545  GOSUB 775
550  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
555 IC = 0
560  IF J = ND THEN  HOME : GOTO
     570
565  HOME : PRINT "BETWEEN DEPT.
     ";I
570  NEXT J
575  NEXT I
580  GOSUB 775
585  PRINT : INPUT "HIT 'RETURN'
     TO CONTINUE ";Y$: HOME
590  RETURN
595  HOME
600  PRINT "NEXT STEP TO BE PERFO
     RMED :"
605  PRINT "     1. EXIT PROGRAM"
610  PRINT "     2. MODIFY EXISTIN
     G DATA"
615  PRINT "     3. INPUT NEW DATA
     "
620  PRINT : PRINT : PRINT
625  PRINT "   ENTER CHOICE # ": GET
     X
630  ON X GOTO 640,875,15
635  PRINT "CHOICE MUST BE 1,2,3,
      OR 4": GOTO 595
640  HOME : END
645  HOME : FOR X = 1 TO 5: PRINT
     : NEXT X
650  PRINT "              PLANT DES
     IGN": PRINT : PRINT "
     PRODUCTION DEPARTMENT": PRINT
     "         RELATIONSHIP CHART"
```

```
655  PRINT
660  PRINT "            IEMS DEPAR
     TMENT"
665  PRINT "              UNIVERSI
     TY "
670  PRINT "                  OF"
675  PRINT "            CENTRAL FL
     ORIDA"
680  FOR X = 1 TO 3000: NEXT X: HOME

685  RETURN
690  STOP
695  FOR J = J TO NP:N(J) = 0
700  PRINT : PRINT : PRINT : PRINT

705 A$(1) = "QUANTITY ":A$(2) = "
     BATCH SIZE ":A$(3) = "DEPT.
     # OF OPERATIONS "
710  FOR X = 1 TO 3: PRINT X;". "
     ;A$(X): NEXT X
715  PRINT : PRINT : PRINT "ENTER
      # OF ITEM TO BE CHANGED ": PRINT
     : INPUT X
720  IF X = 1 THEN 735
725  IF X = 2 THEN 740
730  IF X = 3 THEN 745
735  PRINT : INPUT "ENTER NEW VAL
     UE FOR QUANTITY ";Q(J): RETURN

740  PRINT : INPUT "ENTER NEW VAL
     UE FOR BATCH SIZE ";B(J): RETURN

745  FOR I = 1 TO 25
750  PRINT "ENTER NEW DEPT. # OF
     OPERATION ";I;
755  INPUT " : ";P(J,I)
760  IF P(J,I) = 0 THEN  RETURN
765 N(J) = N(J) + 1: NEXT I
770  RETURN
775  PRINT
780  PRINT "----------------------
     ---------------"
785  PRINT "          .  RELVAL KEY"

790  PRINT "----------------------
     ---------------"
795  PRINT "6: ABSOLUTELY CLOSE 3
     : ORDINARY CLOSE"
```

```
800  PRINT "5: ESPECIALLY CLOSE 2
     : UNIMPORTANT"
805  PRINT "4: IMPORTANT         1
     : UNDESIRABLE"
810  RETURN
815  HOME
820  PRINT : PRINT "   RELATIONSH
     IP VALUES ARE": GOSUB 775
825  PRINT : PRINT : PRINT
830  INPUT " ENTER DEPT. # (FROM)
      ";I
835  INPUT " ENTER DEPT. #   (TO)
      ";J
840  IF I > ND OR I <  = 0 GOTO 8
     55
845  IF J > ND OR J <  = 0 GOTO 8
     55
850  GOTO 860
855  PRINT : PRINT : PRINT " DEPT
     .# OUT OF RANGE": GOTO 830
860  INPUT " ENTER RELVAL
      ";DD(I,J)
865 DD(J,I) = DD(I,J)
870  PRINT : PRINT " OVERRIDE HAS
      BEEN IMPLEMENTED": PRINT : GOTO
     485
875  GOSUB 880: GOTO 250
880  HOME : PRINT : PRINT : PRINT

885  PRINT "ENTER PART# FOR WHICH
      DATA": INPUT "TO BE MODIFIE
     D (0 TO CONTINUE) ";J
890  IF J = 0 THEN 905
895  IF J > NP OR J < 0 THEN  GOTO
     910
900  GOSUB 135: GOTO 880
905  RETURN
910  PRINT : PRINT "** PART# OUT
     OF RANGE **": PRINT : PRINT

915  GOTO 885
920  END
```

Case Example

A company consists of seven production departments (#1 through #7). Products are classified into five groups which have to pass through a specific operation sequence. The volume of production of each group, the bulk factor (Batch size or pieces/load), and the operation sequence are given in Table 2.1, Chapter II.

The Industrial Engineer needs to establish a relationship between the 7 departments so that he can arrange them in a way that satisfies the production requirements for all five groups of products.

After loading the program and typing RUN, the screen displays the name of the program, and the program will start accepting data through the users response to the questions posed. The program begins as follows:

```
]RUN

        PLANT DESIGN

PRODUCTION DEPARTMENT
RELATIONSHIP CHART

    IEMS DEPARTMENT
      UNIVERSITY
          OF
    CENTRAL FLORIDA


ENTER # OF PARTS TO BE PRODUCED 5

ENTER # OF PRODUCTION DEPARTMENTS 7
```

This is followed by a brief statement of program instructions.

```
FOR EACH PART ENTER:

     QUANTITY, BATCH SIZE, SEQUENCE
     OF OPERATIONS

NOTE:

     1- USE DEPT.#'S FOR OPERATIONS

     2- USED DEPT.#'S CAN NOT EXCEED 7

     3- ENTER '0' TO END OPERATIONAL SEQ.

     4- # OF OPERATIONS CAN NOT EXCEED
        50 PER PART



HIT RETURN WHEN READY
```

The required data is now entered.

```
PART # 1
ENTER QUANTITY 100
ENTER BATCH SIZE 7
ENTER DEPT.# FOR OPERATION 1 : 1
ENTER DEPT.# FOR OPERATION 2 : 5
ENTER DEPT.# FOR OPERATION 3 : 4
ENTER DEPT.# FOR OPERATION 4 : 3
ENTER DEPT.# FOR OPERATION 5 : 7
ENTER DEPT.# FOR OPERATION 6 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?Y
```

The opportunity to edit the data is given after entering data for each product group. The correction options are displayed:

1. QUANTITY
2. BATCH SIZE
3. DEPT. # OF OPERATIONS

Corrections are made by entering the number of the item to be changed and the corresponding value

```
ENTER # OF ITEM TO BE CHANGED

?1

ENTER NEW VALUE FOR QUANTITY 700
```

the remaining data is now entered

```
PART # 2
ENTER QUANTITY 12
ENTER BATCH SIZE 1
ENTER DEPT.# FOR OPERATION 1 : 1
ENTER DEPT.# FOR OPERATION 2 : 3
ENTER DEPT.# FOR OPERATION 3 : 2
ENTER DEPT.# FOR OPERATION 4 : 6
ENTER DEPT.# FOR OPERATION 5 : 7
ENTER DEPT.# FOR OPERATION 6 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
PART # 3
ENTER QUANTITY 1000
ENTER BATCH SIZE 20
ENTER DEPT.# FOR OPERATION 1 : 1
ENTER DEPT.# FOR OPERATION 2 : 5
ENTER DEPT.# FOR OPERATION 3 : 7
ENTER DEPT.# FOR OPERATION 4 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
PART # 4
ENTER QUANTITY 390
ENTER BATCH SIZE 30
ENTER DEPT.# FOR OPERATION 1 : 1
ENTER DEPT.# FOR OPERATION 2 : 2
ENTER DEPT.# FOR OPERATION 3 : 3
ENTER DEPT.# FOR OPERATION 4 : 4
ENTER DEPT.# FOR OPERATION 5 : 5
ENTER DEPT.# FOR OPERATION 6 : 6
ENTER DEPT.# FOR OPERATION 7 : 7
ENTER DEPT.# FOR OPERATION 8 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?
PART # 5
ENTER QUANTITY 77
ENTER BATCH SIZE 7
ENTER DEPT.# FOR OPERATION 1 : 1
ENTER DEPT.# FOR OPERATION 2 : 5
ENTER DEPT.# FOR OPERATION 3 : 2
ENTER DEPT.# FOR OPERATION 4 : 3
ENTER DEPT.# FOR OPERATION 5 : 7
ENTER DEPT.# FOR OPERATION 6 : 0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
```

While the computer is calculating the product REL values, the program will display:

```
YOUR COMPUTER IS CALCULATING
    PLEASE STAND BY
```

After the period in which computation takes place, a note is displayed to the user. The layout designer must supply the extreme values for the "Absolutely Necessary" relationship and the "Undesireable" relationship if pertinent. This is done by responding YES to the following questions:

```
NOTE:

 -THE USER MAY SUPPLY CERTAIN RELVALS
  WHICH WILL AUTOMATICALLY OVERRIDE
  THE GENERATED VALUES

 -RELVAL NO.1 AND NO.6 MUST BE SUPPLIED
  BY THE USER IF PERTINENT


  DO YOU WANT TO SUPPLY ANY RELVALS ?

  (Y OR N)  Y
```

A RELVAL KEY is now displayed and the data is input with the following format:

```
   RELATIONSHIP VALUES ARE

-------------------------------------
          RELVAL KEY
-------------------------------------
6: ABSOLUTELY CLOSE 3: ORDINARY CLOSE
5: ESPECIALLY CLOSE 2: UNIMPORTANT
4: IMPORTANT        1: UNDESIRABLE


ENTER DEPT. # (FROM) 1
ENTER DEPT. #   (TO) 7
ENTER RELVAL         6
```

A message is displayed to verify the modifications and the user is given the option to supply additional RELVALs.

```
OVERRIDE HAS BEEN IMPLEMENTED

 DO YOU WANT TO SUPPLY ANY RELVALS ?

 (Y OR N)  N
```

The Departmental Relationship Chart is now displayed

```
      DEPARTMENAL RELATIONSHIP CHART
      ------------------------------

BETWEEN DEPT. 1
          AND DEPT. 1 RELVAL= 0
          AND DEPT. 2 RELVAL= 2
          AND DEPT. 3 RELVAL= 2
          AND DEPT. 4 RELVAL= 2
          AND DEPT. 5 RELVAL= 5
          AND DEPT. 6 RELVAL= 2
          AND DEPT. 7 RELVAL= 6
```

```
BETWEEN DEPT. 2
          AND DEPT. 1 RELVAL= 2
          AND DEPT. 2 RELVAL= 0
          AND DEPT. 3 RELVAL= 2
          AND DEPT. 4 RELVAL= 2
          AND DEPT. 5 RELVAL= 2
          AND DEPT. 6 RELVAL= 2
          AND DEPT. 7 RELVAL= 2
BETWEEN DEPT. 3
          AND DEPT. 1 RELVAL= 2
          AND DEPT. 2 RELVAL= 2
          AND DEPT. 3 RELVAL= 0
          AND DEPT. 4 RELVAL= 2
          AND DEPT. 5 RELVAL= 2
          AND DEPT. 6 RELVAL= 2
          AND DEPT. 7 RELVAL= 2
BETWEEN DEPT. 4
          AND DEPT. 1 RELVAL= 2
          AND DEPT. 2 RELVAL= 2
          AND DEPT. 3 RELVAL= 2
          AND DEPT. 4 RELVAL= 0
          AND DEPT. 5 RELVAL= 2
          AND DEPT. 6 RELVAL= 2
          AND DEPT. 7 RELVAL= 2
BETWEEN DEPT. 5
          AND DEPT. 1 RELVAL= 5
          AND DEPT. 2 RELVAL= 2
          AND DEPT. 3 RELVAL= 2
          AND DEPT. 4 RELVAL= 2
          AND DEPT. 5 RELVAL= 0
          AND DEPT. 6 RELVAL= 2
          AND DEPT. 7 RELVAL= 3
BETWEEN DEPT. 6
          AND DEPT. 1 RELVAL= 2
          AND DEPT. 2 RELVAL= 2
          AND DEPT. 3 RELVAL= 2
          AND DEPT. 4 RELVAL= 2
          AND DEPT. 5 RELVAL= 2
          AND DEPT. 6 RELVAL= 0
          AND DEPT. 7 RELVAL= 2
```

```
BETWEEN DEPT. 7
          AND DEPT. 1 RELVAL= 6
          AND DEPT. 2 RELVAL= 2
          AND DEPT. 3 RELVAL= 2
          AND DEPT. 4 RELVAL= 2
          AND DEPT. 5 RELVAL= 3
          AND DEPT. 6 RELVAL= 2
          AND DEPT. 7 RELVAL= 0

-------------------------------------
            RELVAL KEY
-------------------------------------
6: ABSOLUTELY CLOSE 3: ORDINARY CLOSE
5: ESPECIALLY CLOSE 2: UNIMPORTANT
4: IMPORTANT        1: UNDESIRABLE

HIT 'RETURN' TO CONTINUE
```

finally, program options are now displayed

```
NEXT STEP TO BE PERFORMED :
    1. EXIT PROGRAM
    2. MODIFY EXISTING DATA
    3. INPUT NEW DATA


   ENTER CHOICE #
```

From \ To	1	2	3	4	5	6	7
1	0	2	2	2	5	2	6
2	2	0	2	2	2	2	2
3	2	2	0	2	2	2	2
4	2	2	2	0	2	2	2
5	5	2	2	2	0	2	3
6	2	2	2	2	2	0	2
7	6	2	2	2	3	2	0

Figure 4.1. Relationship chart summarizing the closeness relationship between the production departments using case example.

CHAPTER V

CORELAP

Introduction

CORELAP (Computerized Relationship Layout Planning) was originally presented by Lee and Moore [9]. This program is considered a construction type and it is not limited to production plants. CORELAP can be used to aid in the design of layouts where a relationship between plant departments was established. The minimum input requirements for CORELAP include:

1. Relationship Chart (REL Chart) between the departments, using standard closeness ratings (Table 5.1).
2. Departmental areas.
3. Weights for the REL Chart entries.

The REL Chart provides the basis for the order in which departments are arranged in the layout. The algorithm assigns numerical values to the closeness ratings and these values are added for each department to produce the total closeness rating for departments. This total represents the importance of each department in the layout with respect to other departments. The algorithm places the department having the largest total closeness rating is the middle of the layout.

TABLE 5.1

RELVAL KEY
A = Absolutely necessary.
E = Especially important.
I - Important.
O = Ordinary closeness desired.
U = Unimportant.
X = Undesireable.

The arrangement routine used in this program, originally presented by Hosni [4], is an adapted version of CORELAP. Specific assumptions are made which can be summarized as follows:

1. Departments are arranged in bays.

2. Departments are rectangular in shape, with its width equal to the bay width, and its length is computed based on department area.

This arrangement scheme places the department having the largest total closeness rating in the middle of the layout. The arrangement is expanded to the right and to the left of the "physical" middle, satisfying the "needs" of closeness as represented by the REL Chart. (see Figure 5.1).

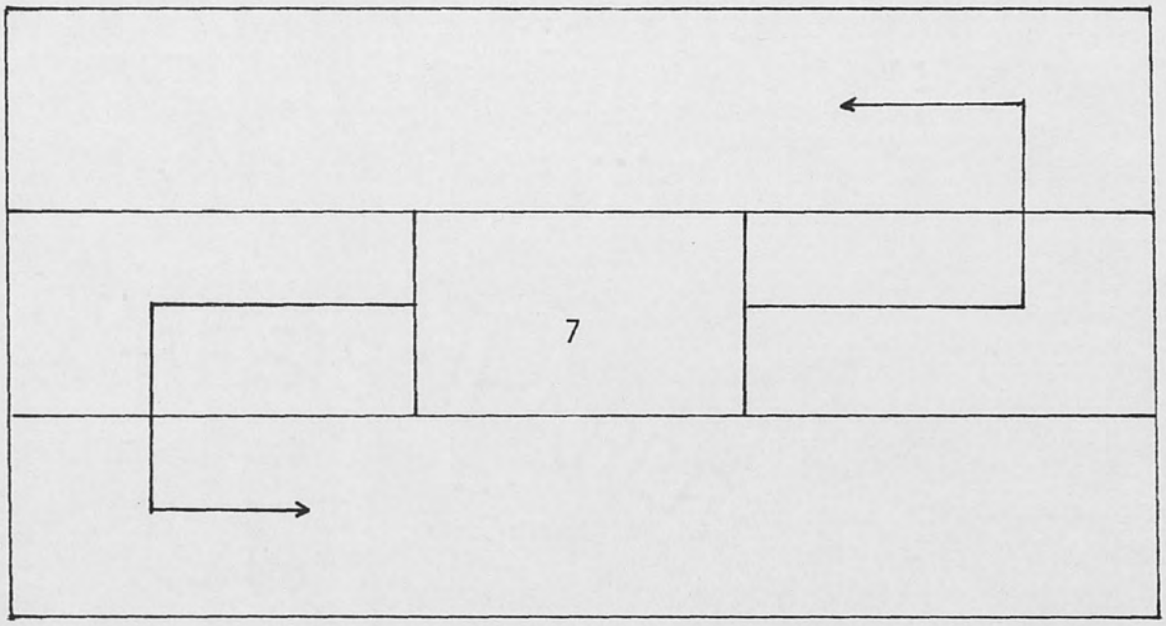


Figure 5.1. Arrangement scheme which places most important department in the "physical" middle of the layout, and expands to the right and left, continuing in the next bays as shown.

This scheme is achieved by considering the plant bays as one continuous bay. The length is equal to the number of bays * area length. The algorithm determines the center and assigns the most important department. The algorithm keeps adding the different department lengths according to their closeness ratings, to the right and to the left. Each time there is an addition of a department either to the right or to the left, the bay is checked if it is full. If one side is filled, the arrangement continues on the other side. There is no way that the bays would not accomodate all the departments since the available space requirements are checked for sufficiency prior to the arrangement routine.

Advantages of CORELAP

1. This program takes into consideration the qualitative factors influencing the arrangement of departments as represented in the REL Chart.

2. CORELAP is a construction program, i.e., no initial layout is required.

Limitations of CORELAP

1. Original version of CORELAP is impractical with respect to the production plants because the final output design usually has "zig-zagging" boundaries in a way that it would be difficult to use material handling equipment *. However, the adapted version of CORELAP presented in this program eliminates this "zig-zagging" effect by constricting departments within boundaries of the bay.

2. CORELAP produces a single final layout, therefore no alternative designs are available for selection.

---

* The "zig-zagging" might be useful in satisfying the REL Chart requirements.

Program Documentation

Program Name: CORELAP (Computerized Relationship Layout Planning).

Program Function: CORELAP is a construction type program. It accepts a Relationship Chart between departments and produces a final layout.

Program Input:

1. Number of production departments.
2. REL values between departments expressed in numerical values (A≡6, E≡5, I≡4, O≡3, U≡2, X≡1).
3. Length of available area.
4. Width of available area.
5. Number of bays desired.
6. Departmental areas.

Program Logic:

1. Accept Input (REL Chart ≡N X N).
2. Display data and accept changes if any, if not, continue.
3. Department total closeness ratings are computed and displayed.

   Total Closeness Rating

$$\text{Dept.}_{i} = \sum_{j=1}^{N} \text{REL values} \quad \text{--- for } i = 1,2,..,N$$

4. Departments are sorted according to their total closeness ratings.
5. Departments are arranged by placing the department having the largest total closeness rating in the middle of the layout. The algorithm keeps adding the different department lengths according to their closeness ratings, to the right and to the left. Each time there is an addition of a department either to the right or left, the bay is checked if it is full. If one side is filled, the arrangement continues on the other side.

6. Layout arrangement is displayed in terms of XY - coordinates and distance matrix. (Refer to Chapter III).

Program Output: Layout arrangement in terms of XY - coordinates for department areas and a rectilinear distance matrix.

Program Listing

```
10  REM  **PLANT LAYOUT-DEPARTMEN
     TAL RELATIONSHIP CHART
15  GOSUB 190
20  CLEAR
25  PRINT : PRINT : PRINT
30  INPUT "ENTER # OF PRODUCTION
     DEPARTMENTS ";ND
35  DIM DD(ND,ND)
40  PRINT
45  HOME
50  FOR RT = 1 TO 3: PRINT : NEXT
     RT
55  PRINT "INPUT THE RELVALS BETW
     EEN DEPARTMENTS"
60  PRINT : PRINT
65  PRINT "   DEPARTMENAL RELATIO
     NSHIP CHART": PRINT "   ----
     ----------------------------"
     : PRINT
70  FOR I = 1 TO ND
75  PRINT "BETWEEN DEPT. ";I
80  FOR J = 1 TO ND
85  IF J = I GOTO 130
90  PRINT "          AND DEPT. ";J
     ;: INPUT " RELVAL = ";DD(I,J
     )
95 IC = IC + 1
100  IF IC < 9 THEN 130
105  GOSUB 235
110  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
115 IC = 0
120  IF J = ND THEN  HOME : GOTO
     130
125  HOME : PRINT "BETWEEN DEPT.
     ";I
130  NEXT J
135  NEXT I
140  GOSUB 235
145  PRINT
150  INPUT "DO YOU WANT TO MAKE A
     NY CHANGES(Y OR N) ";Y$
155  IF Y$ = "N" GOTO 275
160  IF Y$ = "Y" GOTO 165
```

```
165  HOME : PRINT : PRINT
170  INPUT "CHANGE DATA FROM DEPT
     . ";I2
175  INPUT "                TO DEPT
     . ";J2
180  INPUT "                RELVAL
     = ";DD(I2,J2)
185  PRINT : PRINT "  ** CHANGE I
     MPLEMENTED **": GOTO 150
190  HOME : FOR X = 1 TO 5: PRINT
     : NEXT X
195  PRINT "                 CORELA
     P"
200  PRINT
205  PRINT "            IEMS DEPAR
     TMENT"
210  PRINT "              UNIVERSI
     TY "
215  PRINT "                   OF"
220  PRINT "            CENTRAL FL
     ORIDA"
225  FOR X = 1 TO 3000: NEXT X: HOME

230  RETURN
235  PRINT
240  PRINT "-------------------
     ---------------"
245  PRINT "           RELVAL KEY"

250  PRINT "-------------------
     -------------"
255  PRINT "6: ABSOLUTELY CLOSE 3
     : ORDINARY CLOSE"
260  PRINT "5: ESPECIALLY CLOSE 2
     : UNIMPORTANT"
265  PRINT "4: IMPORTANT        1
     : UNDESIRABLE"
270  RETURN
275  REM  ** CRAFT **
280  FOR X = 1 TO 4: PRINT : NEXT
     X
285  HOME : PRINT : PRINT
290  INPUT "ENTER TOTAL BAY LENGT
     H ";BL: PRINT
295  INPUT "ENTER WIDTH OF AVAILA
     BLE AREA  ";BW: PRINT
300  PRINT "*******************
     ****************"
```

```
305 Z = BL * BW: PRINT "TOTAL SPA
    CE AVAILABLE = ";Z;" SQ.UNIT
    S"
310  PRINT "**********************
    ********************": PRINT
315  INPUT "ENTER # OF BAYS DESIR
    ED ";NB
320  PRINT
325  PRINT "**********************
    ********************"
330 BS = BW / NB
335  PRINT "BAY SPAN = ";BS
340  PRINT "**********************
    ********************": PRINT :
     PRINT
345  PRINT "HIT RETURN TO CONTINU
    E ";: GET Y$
350  DIM BAC(NB),BL(NB,25),B(NB,2
    5)
355  DIM X1(NB,25),Y1(NB,25),X2(N
    B,25),Y2(NB,25)
360  DIM DA(50),DN(50),DL(50),DB(
    25),FG(10),FB(10)
365  DIM RG(50),SL(50),RF(50),LF(
    50),TL(50),TM(50),MT(50)
370  HOME : FOR X = 1 TO 5: PRINT
    : NEXT X
375 BB = 0
380  PRINT "**********************
    ********************"
385  PRINT "FOR THE FOLLOWING SEQ
    UENCE"
390  PRINT "ENTER :  DEPT.#,AREA
395  PRINT "**********************
    ********************"
400 R1 = 0:R2 = 0:D1 = 0:F = 1:S =
    0:BB = 0
405  FOR I = 1 TO NB:BAC(I) = 0: NEXT
    I
410  FOR I = 1 TO NB:DB(I) = 0: NEXT
    I
415 TT = 0
420  FOR I = 1 TO NB:FG(I) = 0: NEXT
    I
425  PRINT
430  PRINT "SEQUENCE,DEPT.#,AREA"

435  PRINT "--------------------"

440  FOR J = 1 TO ND
445 BB = BB + 1
```

```
450  PRINT "     "$BB$: INPUT "
       "$DN(J),DA(J)
455 MT(J) = DA(J)
460 DL(J) = DA(J) / BS
465 TT = TT + DA(J)
470  IF TT > Z GOTO 1280
475  NEXT J
480  FOR I = 1 TO ND
485  FOR J = 1 TO ND
490 RG(I) = RG(I) + DD(I,J)
495  NEXT J
500  NEXT I
505  HOME : PRINT : PRINT
510  PRINT "**********************
     *****"
515  PRINT "      DEPARTMENT RATIN
     G"
520  PRINT "**********************
     *****": PRINT : PRINT
525  PRINT "      DEPT.#     RATING
     "
530  PRINT "----------------------
     ------": PRINT
535  FOR I = 1 TO ND
540 DN(I) = I
545  PRINT "       "$DN(I)$"
      "$RG(I)
550  NEXT I
555  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE"$: GET Y$
560  HOME
565 N1 = ND - 1
570  FOR I = 1 TO N1
575 J = I + 1
580  IF RG(I) >  = RG(J) GOTO 655

585 SG = RG(I)
590 RG(I) = RG(J)
595 RG(J) = SG
600 SQ = DN(I)
605 DN(I) = DN(J)
610 DN(J) = SQ
615 DQ = DA(I)
620 DA(I) = DA(J)$DA(J) = DQ
625  FOR JJ = 1 TO ND   ,
630 SL(JJ) = DD(I,JJ)
635 DD(I,JJ) = DD(J,JJ)
640 DD(J,JJ) = SL(JJ)
645  NEXT JJ
650  GOTO 570
655  NEXT I
```

```
670  PRINT "       SORTING BY RATI
     NG"
675  PRINT "**********************
     *********"
680  PRINT : PRINT : PRINT
685  PRINT "    DEPT.#       RATIN
     G"
690  PRINT "----------------------
     -----": PRINT
695  FOR I = 1 TO ND
700 DL(I) = DA(I) / BS
705  PRINT "       ";DN(I);"
       ";RG(I)
710  NEXT I
715  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
720  HOME
725 LN = NB * BL
730 CN = LN / 2
735 I1 = 1
740 I2 = 1
745 LS = DL(1) / 2
750 RS = DL(1) / 2
755 LF(I1) = DN(1)
760 RF(I2) = DN(1)
765  FOR I = 2 TO ND STEP 2
770 J = I
775  IF LS >  = CN GOTO 800
780 LS = LS + DL(J)
785 I1 = I1 + 1
790 LF(I1) = DN(J)
795 J = J + 1
800  IF RS >  = CN GOTO 775
805  IF J > ND GOTO 825
810 RS = RS + DL(J)
815 I2 = I2 + 1
820 RF(I2) = DN(J)
825  NEXT I
830  FOR I = 1 TO ND
835 DN(I) = LF(I1)
840 I1 = I1 - 1
845  IF I1 = 0 GOTO 855
850  NEXT I
855 J1 = 1
860  FOR J = I TO ND
865 DN(J) = RF(J1)
870 J1 = J1 + 1
```

```
875  IF J1 > I2 GOTO 885
880  NEXT J
885  FOR I = 1 TO ND
890 FK = DN(I)
895 TM(I) = MT(FK)
900 DA(I) = TM(I)
905  NEXT I
910  PRINT : PRINT : PRINT
915  PRINT "**********************
     ***************"
920  PRINT "ARRANGEMENT-HIGHEST R
     ATING IN CENTER
925  PRINT "**********************
     ***************"
930  PRINT : PRINT : PRINT
935  PRINT "     DEPT.#       LENG
     TH"
940  PRINT "--------------------
     -------": PRINT
945  FOR I = 1 TO ND
950 DL(I) = DA(I) / BS
955  PRINT "        ";DN(I);"
         ";DL(I)
960  NEXT I
965  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
970  FOR I = 1 TO NB
975 R1 = 0:D1 = 0
980  FOR J = F TO ND
985 S = S + 1
990 DL(J) = DA(J) / BS
995 BAC(I) = BAC(I) + DL(J)
1000  IF BAC(I) < BL GOTO 1015
1005  IF BAC(I) = BL GOTO 1055
1010  IF BAC(I) > BL GOTO 1095
1015 R1 = BL - BAC(I)
1020  IF R1 < 10 GOTO 1040
1025 BL(I,S) = DL(J)
1030 B(I,S) = DN(J)
1035  GOTO 1050
1040 DL(J) = DL(J) + R1
1045  GOTO 1055
1050  NEXT J
1055 BL(I,S) = DL(J)
1060 B(I,S) = DN(J)
1065 DB(I) = J - F + 1
1070  IF FG(I) = 1 THEN DB(I) = D
     B(I) + 1
1075 F = J + 1
1080 FB = 0
```

```
1085 S = 0
1090  GOTO 1190
1095 R1 = BAC(I) - BL
1100  IF R1 < 10 GOTO 1180
1105 R2 = DL(J) - R1
1110 BL(I,S) = R2
1115 B(I,S) = DN(J)
1120 FB(I) = 1
1125 DB(I) = J - F + 1
1130  IF FG(I) = 1 THEN DB(I) = D
     B(I) + 1
1135 M = I + 1
1140 FG(M) = 1
1145 D1 = DN(J)
1150 BAC(M) = BAC(M) + R1
1155 BL(M,1) = R1
1160 B(M,1) = D1
1165 S = 1
1170 F = J + 1
1175  GOTO 1190
1180 DL(J) = DL(J) - R1
1185  GOTO 1055
1190  NEXT I
1195  PRINT : PRINT
1200  HOME
1205  FOR I = 1 TO NB
1210  IF BL(I,1) = 0 GOTO 1220
1215  GOTO 1270
1220 J1 = DB(I)
1225 J1 = J1 - 1
1230  FOR J = 1 TO J1
1235 J2 = J + 1
1240 BL(I,J) = BL(I,J2)
1245 B(I,J) = B(I,J2)
1250  NEXT J
1255 DB(I) = DB(I) - 1
1260 M = I - 1
1265 DB(M) = DB(M) - 1
1270  NEXT I
1275  GOTO 1295
1280  PRINT : PRINT : PRINT "****
     **************************
     ******"
1285  PRINT "THE TOTAL AVAILABLE
     SPACE REQUIREMENTS": PRINT "
     HAVE BEEN EXCEEDED BY ";TT -
     Z;" SQ.UNITS
1290  PRINT "********************
     ******************": PRINT
```

```
1295  HOME : PRINT : PRINT : PRINT
     : PRINT
1300  PRINT "       SUBROUTINE CAL
     CULATING"
1305  PRINT
1310  PRINT "          XY-COORDINA
     TES"
1315  FOR X = 1 TO 3000: NEXT X
1320  HOME
1325  FOR I = 1 TO NB
1330  IF I = 1 GOTO 1355
1335  IF I = 3 GOTO 1355
1340 F = I / 2
1345 F = F * 2
1350  IF F = I GOTO 1405
1355 X1(I,1) = 0
1360 N1 = DB(I)
1365 XC(I,1) = BL(I,1) / 2
1370  FOR J = 1 TO N1
1375 X2(I,J) = X1(I,J) + BL(I,J)
1380 J1 = J + 1
1385  IF J = N1 GOTO 1395
1390 X1(I,J1) = X2(I,J)
1395  NEXT J
1400  GOTO 1450
1405 N1 = DB(I)
1410 X2(I,1) = BL
1415  FOR J3 = 1 TO N1
1420 X1(I,J3) = X2(I,J3) - BL(I,J
     3)
1425 J2 = J - 1
1430 J4 = J3 + 1
1435  IF J3 = N1 GOTO 1445
1440 X2(I,J4) = X1(I,J3)
1445  NEXT J3
1450  NEXT I
1455 Y1(1,1) = BW
1460  FOR I = 1 TO NB
1465 N1 = DB(I)
1470  FOR J = 1 TO N1
1475 Y1(I,J) = Y1(I,1)
1480 Y2(I,J) = Y1(I,J) - BS
1485  NEXT J
1490  IF I = NB GOTO 1505
1495 I2 = I + 1
1500 Y1(I2,1) = Y2(I,1)
1505  NEXT I
1510  FOR I = 1 TO NB
1515 J2 = DB(I)
1520  FOR J = 1 TO J2
```

```
1525 XC(I,J) = (X1(I,J) + ((BL(I,
     J)) / 2.0))
1530  NEXT J
1535  NEXT I
1540 HALF = 0.5 * BS
1545 YC(1,1) = Y1(1,1) - HALF
1550 J6 = DB(I)
1555  FOR J = 1 TO J6
1560 YC(1,J) = YC(1,1)
1565  NEXT J
1570  FOR I = 2 TO NB
1575 J6 = DB(I)
1580  FOR J = 1 TO J6
1585 I2 = I - 1
1590 YC(I,J) = YC(I2,1) - BS
1595  NEXT J
1600  NEXT I
1605  HOME : PRINT : PRINT
1610  PRINT "      XY-COORDINATES
     CHART"
1615  PRINT "     ----------------
     -------": PRINT : PRINT
1620  PRINT "SEQ ";"DEP ";"X1    "
     ;"Y1    ";"X2    ";"Y2    ";"XC
        ";"YC"
1625  PRINT "---------------------
     --------------------"
1630 BB = 0
1635  FOR I = 1 TO NB
1640 J1 = DB(I)
1645  FOR J = 1 TO J1
1650 BB = BB + 1
1655 Y1(I,J) =  ABS (Y1(I,J) - BW
     )
1660 Y2(I,J) =  ABS (Y2(I,J) - BW
     )
1665 YC(I,J) =  ABS (YC(I,J) - BW
     )
1670 YC(1,J) = YC(1,1)
1675  PRINT " ";BB;"    ";B(I,J); TAB(
     9);X1(I,J); TAB( 14);Y1(I,J)
     ; TAB( 19);X2(I,J); TAB( 24)
     ;Y2(I,J); TAB( 29);XC(I,J); TAB(
     34);YC(I,J)
1680  NEXT J
1685  NEXT I
1690  FOR I = 1 TO NB
1695 J1 = DB(I)
1700 M = I + 1
1705  IF M > NB GOTO 1805
```

```
1715  NEXT I
1720  GOTO 1805
1725 M = 0
1730  FOR I = 1 TO NB
1735 J1 = DB(I)
1740 M = I + 1
1745  IF M > NB GOTO 1805
1750  IF BL(I,J1) > BL(M,1) GOTO
     1765
1755 XC(I,J1) = XC(M,1):YC(I,J1) =
     YC(M,1)
1760  GOTO 1770
1765 XC(M,1) = XC(I,J1):YC(M,1) =
     YC(I,J1)
1770  NEXT I
1775  GOTO 1715
1780  IF M > NB GOTO 1805
1785  IF BL(I,J1) > BL(M,1) GOTO
     1795
1790  GOTO 1800
1795 XC(M,1) = XC(I,J1):YC(M,1) =
     YC(I,J1)
1800  NEXT I
1805  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE";: GET Y$
1810  HOME
1815  FOR I = 1 TO ND
1820  FOR J = 1 TO ND
1825 DS(I,J) = 99999
1830  NEXT J
1835  NEXT I
1840  FOR I = 1 TO NB
1845 J2 = DB(I)
1850  FOR J = 1 TO J2
1855  FOR I1 = 1 TO NB
1860 J3 = DB(I)
1865  FOR J1 = 1 TO J3
1870 J5 = B(I,J)
1875 J4 = B(I1,J1)
1880 D1 =  ABS (XC(I,J) - XC(I1,J
     1))
1885 D1 = D1 +  ABS (YC(I,J) - YC
     (I1,J1))
1890  IF D1 <  = DS(J5,J4) THEN D
     S(J5,J4) = D1
1895  NEXT J1
1900  NEXT I1
1905  NEXT J
1910  NEXT I
1915  PRINT : PRINT : PRINT
```

```
1920  PRINT : PRINT "  DISTANCE-M
     ATRIX"
1925  PRINT "--------------------"

1930 J = 0
1935  FOR F = 1 TO ND
1940  FOR F1 = 1 TO ND
1945  IF DS(F,F1) < DS(F1,F) THEN
     DS(F1,F) = DS(F,F1)
1950  IF DS(F1,F) < DS(F,F1) THEN
     DS(F,F1) = DS(F1,F)
1955 J = J + 1
1960 A = A + 5
1965  IF JP = 1 GOTO 1975
1970  PRINT DS(F,F1); TAB( A);
1975  IF J = ND THEN J = 0: PRINT

1980  NEXT F1
1985 A = 0
1990  NEXT F
1995  PRINT : PRINT : PRINT "HIT
     'RETURN' TO CONTINUE ";: GET
     Y$
2000  HOME : PRINT : PRINT : PRINT
     : INPUT "DO YOU WANT TO EXIT
      PROGRAM (Y OR N)? ";B$: IF
     B$ = "Y" THEN 2010
2005  GOTO 10
2010  END
```

Case Example

A company consists of five production departments (#1 through #5). The Industrial Engineer established a relationship between the five departments as follows:

From \ To	1	2	3	4	5
1	0	5	3	4	6
2	5	0	5	6	6
3	3	5	0	6	4
4	4	6	6	0	5
5	6	6	4	5	0

The Industrial Engineers desire is to construct a layout arrangement to satisfy this Relationship Chart.

After loading the program and typing RUN, the screen displays the following:

```
]RUN

                    CORELAP

                  IEMS DEPARTMENT
                    UNIVERSITY
                       OF
                  CENTRAL FLORIDA
```

The required data is now entered by answering the pertinent questions:

```
ENTER # OF PRODUCTION DEPARTMENTS 5


INPUT THE RELVALS BETWEEN DEPARTMENTS

     DEPARTMENAL RELATIONSHIP CHART
     ------------------------------

BETWEEN DEPT. 1
          AND DEPT. 2 RELVAL = 5
          AND DEPT. 3 RELVAL = 3
          AND DEPT. 4 RELVAL = 4
          AND DEPT. 5 RELVAL = 6
```

```
BETWEEN DEPT. 2
          AND DEPT. 1 RELVAL = 5
          AND DEPT. 3 RELVAL = 5
          AND DEPT. 4 RELVAL = 6
          AND DEPT. 5 RELVAL = 6
BETWEEN DEPT. 3
          AND DEPT. 1 RELVAL = 3
          AND DEPT. 2 RELVAL = 5
          AND DEPT. 4 RELVAL = 6
          AND DEPT. 5 RELVAL = 4
BETWEEN DEPT. 4
          AND DEPT. 1 RELVAL = 4
          AND DEPT. 2 RELVAL = 6
          AND DEPT. 3 RELVAL = 6
          AND DEPT. 5 RELVAL = 5
BETWEEN DEPT. 5
          AND DEPT. 1 RELVAL = 6
          AND DEPT. 2 RELVAL = 6
          AND DEPT. 3 RELVAL = 4
          AND DEPT. 4 RELVAL = 5

-----------------------------------------
            RELVAL KEY
-----------------------------------------
6: ABSOLUTELY CLOSE 3: ORDINARY CLOSE
5: ESPECIALLY CLOSE 2: UNIMPORTANT
4: IMPORTANT        1: UNDESIRABLE

DO YOU WANT TO MAKE ANY CHANGES,(Y OR N)? N
```

The dimensions of the space available are now entered

```
ENTER TOTAL BAY LENGTH 100
ENTER WIDTH OF AVAILABLE AREA  50
```

and the total space available is computed.

```
**************************************
TOTAL SPACE AVAILABLE = 5000 SQ.UNITS
**************************************
```

The number of bays desired are now entered

```
ENTER # OF BAYS DESIRED 2
```

and the bay span to calculated.

```
**************************************
BAY SPAN = 25
**************************************
```

The remaining data is now entered.

```
**************************************
FOR THE FOLLOWING SEQUENCE
ENTER :  DEPT.#,AREA
**************************************

SEQUENCE,DEPT.#,AREA
--------------------
     1          1,700
     2          5,1000
     3          2,800
     4          4,1800
     5          3,700
```

The total closeness ratings are now computed and displayed.

```
**************************
     DEPARTMENT RATING
**************************

     DEPT.#     RATING
-------------------------

       1         18
       2         22
       3         18
       4         21
       5         21
```

The departments are sorted according to their total closeness ratings and then displayed to the user.

```
**********************************
       SORTING BY RATING
**********************************
```

DEPT.#	RATING
2	22
4	21
5	21
1	18
3	18

The program now arranges the departments on the basis of total closeness ratings.

```
**************************************
ARRANGEMENT-HIGHEST RATING IN CENTER
**************************************
```

DEPT.#	LENGTH
1	28
4	72
2	40
5	28
3	32

While computing the XY - Coordinates, the program will display the following:

SUBROUTINE CALCULATING

XY-COORDINATES

After the period in which computation takes place, the results are displayed.

XY-COORDINATES CHART

SEQ	DEP	X1	Y1	X2	Y2	XC	YC
1	1	0	0	28	25	14	12.5
2	4	28	0	100	25	64	12.5
3	2	60	25	100	50	80	37.5
4	5	32	25	60	50	46	37.5
5	3	0	25	32	50	16	37.5

DISTANCE-MATRIX

0	91	27	50	57
91	0	64	41	34
27	64	0	73	30
50	41	73	0	43
57	34	30	43	0

Finally program options are now displayed.

DO YOU WANT TO EXIT PROGRAM,(Y OR N)? Y

CHAPTER VI

LAYOUT EVALUATION

Introduction

It is the purpose of this chapter to present a computer program written in Interactive Basic that evaluates a layout arrangement and provides guidelines for rearrangement with respect to satisfying a relationship chart.

The layout evaluation technique was developed by Hosni [4] to guide the layout designer in generating more efficient layout designs.

A product equivalent relationship chart between the production departments is generated by accepting product data. The criteria considered in creating these relationships are product volume, material flow, product design, and sequence of processing. The product REL Chart represents a measure of activity relationships by performing pairwise evaluations of the importance for two activities to be located together in the layout.

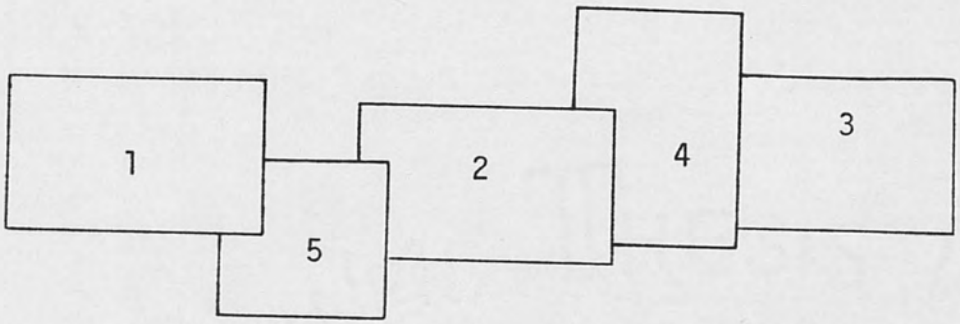
The closeness relationship between the product departments are assigned the following ratings:

Relationship	Closeness Rating
Absolute necessary	6
Especially important	5
Important	4
Ordinary closeness	3
Unimportant	2
Undesireable	1

The layout designer must supply the extreme values for the "Absolutely Necessary" relationship and the "Undesireable relationship.

A layout REL Chart is formed using equivalent measures to those used in generating the Product REL Chart. The algorithm considers the adjacent departments as having a closeness rating of "6"; the departments separated by one department in between, a rating of "5"; those departments separated by two departments in between, a rating of "4"; etc. A demonstrating example is shown in Figure 6.1.

1. Layout Arrangement.



2. Translation as Input Data.

Dept.	Adjacents
1	5
2	5,4
3	4
4	2,3
5	1,2

3. Equivalent Layout REL Chart.

	1	2	3	4	5
1	0	5	3	4	6
2	5	0	5	6	6
3	3	5	0	6	4
4	4	6	6	0	5
5	6	6	4	5	0

Figure 6.1. Translation of layout arrangement and generation of an equivalent layout REL chart.

This algorithm also scores the arrangement, analyzing it and producing an efficiency value. This is achieved by comparing both the layout relationship chart and the product relationship chart. Grading is performed by subtracting the two matrices of the relationship and scoring the difference as follows:

Difference	Grade
0 (or negative)	5
1	4
2	3
3	2
4	1
5	Error

The grades of all the relationships are added together to produce a total score. Once the evaluation scoring has been determined, suggestions to generate alternative layout designs and the corresponding maximum increase in efficiency can be deduced.

Program Documentation

Program Name: Layout Evaluation.

Program Function: Evaluates present layout design and identifies those departments which if become more adjacent, will result in a more efficient layout.

Program Input:

1. Number of production departments.
2. REL values with respect to the product.
3. The corresponding adjacent departments for each department. (See case example).

Program Logic:

1. Accept input.
2. Display data, make corrections if any, if not, continue.
3. Relationship chart with respect to the layout is formed.
   - adjacent departments have a closenss rating of "6".
   - departments separated by one department in between a rating of "5".
   - departments separated by two departments in between, a rating of "4"; etc. (See Figure 6.1.)
4. Subtract product equivalent relationship chart from layout equivalent relationship chart to produce an evaluation scoring between departments.
   - difference of 0 (or negative), a grade of "5".
   - difference of 1, a grade of "4".
   - difference of 2, a grade of "3"; etc.
   - difference of 5 or greater produces an error.

5. The grades of all the relationships are added together to produce a total score, Once the evaluation scoring has been determined, suggestions of which departments should become more adjacent to provide a more efficient lay-out design can be deduced.

Program Output:

1. Relationship Chart with respect to the layout.
2. Evaluation scoring for each department.
3. Recommended improvements.

Program Listing

```
10  REM  **PLANT LAYOUT EVALUATIO
    N**
15  GOSUB 1030
20  HOME
25  PRINT : PRINT : INPUT "DO YOU
    NEED INSTRUCTIONS (Y OR N)
    ";Y$
30  IF Y$ = "Y" THEN  GOSUB 45: GOTO
    120
35  IF Y$ = "N" THEN 120
40  GOTO 25
45  HOME : PRINT : PRINT
50  PRINT "THIS PROGRAM IS DESIGN
    ED TO EVALUATE"
55  PRINT "A DEPARTMENTAL ARRANGE
    MENT (LAYOUT)"
60  PRINT "WITH RESPECT TO SATISF
    YING A"
65  PRINT "RELATIONSHIP CHART TO
    BE SUPPLIED ": PRINT "BY THE
     USER. EVALUATION CRITERIA":
     PRINT "IS THE PROXIMITY BET
    WEEN DEPARTMENTS.": PRINT
70  PRINT "PROGRAM ACCEPTS A RELA
    TIONSHIP CHART": PRINT "USIN
    G THE FOLLOWING 'RELVAL'S :"

75  PRINT "              RELVAL KEY
    "
80  PRINT "6: ABSOLUTELY CLOSE 3:
     ORDINARY CLOSE"
85  PRINT "5: ESPECIALLY CLOSE 2:
     UNIMPORTANT"
90  PRINT "4: IMPORTANT         1:
     UNDESIRABLE"
95  PRINT
100  PRINT "IT ACCEPTS DATA FOR T
    HE LAYOUT IN": PRINT "THE FO
    RM OF DEPT.# AND THE #'S OF"
    : PRINT "DEPTS. ADJACENT TO
    IT.": PRINT
105  PRINT "PROGRAM SCORES THE LA
    YOUT AND": PRINT "RECOMMENDS
     IMPROVEMENTS."
110  PRINT : PRINT "HIT ' RETURN'
     WHEN READY ": GET A$
```

```
115  RETURN
120  HOME
125  FOR I = 1 TO 8: PRINT : NEXT
     I
130  INPUT "ENTER THE # OF DEPART
     MENTS ";ND
135  DIM D(ND,ND),DD(ND,ND),E(ND,
     21)
140  HOME
145  FOR I = 1 TO ND
150 J1 = I + 1
155  IF J1 > ND AND I = ND THEN 2
     25
160  PRINT "ENTER RELVAL BETWEEN
     DEPT. ";I
165  FOR J = J1 TO ND
170  PRINT "                    AND
     DEPT. ";J;" = ";: INPUT DD(I
     ,J)
175  IF DD(I,J) > 6 OR DD(I,J) <
     1 THEN  PRINT "RELVAL SHOULD
      BE BETWEEN 1 & 6 ": PRINT "
     REENTER": GOTO 170
180 IC = IC + 1
185  IF IC < 16 THEN 215
190  GOSUB 1115
195  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
200 IC = 0
205  IF J = ND THEN  HOME : GOTO
     215
210  HOME : PRINT "ENTER RELVAL B
     ETWEEN DEPT. ";I
215  NEXT J
220  NEXT I
225  GOSUB 1115
230  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE ";: GET Y$
235  HOME : PRINT : PRINT
240  REM ** RELATIONSHIP  CHART W
     .R.T. ADJACENT DEPTS.
245  PRINT "              INPUT DAT
     A FOR": PRINT "        LAYOU
     T TO BE EVALUATED"
250  PRINT : PRINT
255  PRINT "  FOR EACH DEPT., ENT
     ER THE # OF": PRINT "  CORRE
     SPONDING ADJACENT DEPTS."
```

```
260  PRINT : PRINT
265  PRINT "NOTE:": PRINT "-----"
     : PRINT : PRINT "    . NO. O
     F ADJACENT DEPTS.NOT TO": PRINT
     "       EXCEED 20.": PRINT : PRINT
     "    . ENTER '0' TO END SEQU
     ENCE OF": PRINT "       ADJAC
     ENT DEPTS."
270  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE": GET Y$: HOME
275  FOR I = 1 TO ND
280  HOME
285  PRINT "FOR DEPT. # ";I
290  FOR J = 1 TO 20
295  PRINT "    ADJACENT DEPT. ";
     J;" IS ";: INPUT E(I,J)
300  IF E(I,J) > ND THEN  PRINT "
      DEPT.# CAN NOT EXCEEDS ";ND
     : PRINT "REENTER": GOTO 295
305  IF E(I,J) = I THEN  PRINT "D
     EPT. CANNOT BE ADJACENT TO I
     TSELF": PRINT "REENTER": GOTO
     295
310  IF E(I,J) = 0 THEN 325
315  NEXT J
320  PRINT : PRINT
325  PRINT : INPUT "DO YOU WANT T
     O MAKE CHANGES, (Y OR N)?";B
     $: IF B$ = "Y" THEN  GOSUB 1
     075
330  HOME
335  NEXT I
340  PRINT : PRINT : PRINT : PRINT
     "   YOUR COMPUTER IS CALCULA
     TING"
345  FOR I = 1 TO ND
350  FOR J = 1 TO ND
355 D(I,J) = 0
360  NEXT J
365  NEXT I
370  FOR I = 1 TO ND
375  FOR J = 1 TO 21
380 J1 = E(I,J)
385  IF J1 = I GOTO 545
390  IF J1 = 0 GOTO 550
395  IF D(I,J1) > 6 GOTO 405
```

```
400 D(I,J1) = 6
405  FOR K = 1 TO 21
410 K1 = E(J1,K)
415  IF K1 = 0 GOTO 545
420  IF K1 = I GOTO 540
425  IF D(I,K1) > 5 GOTO 435
430 D(I,K1) = 5
435  FOR L = 1 TO 21
440 L1 = E(K1,L)
445  IF L1 = 0 GOTO 540
450  IF L1 = I GOTO 535
455  IF D(I,L1) > 4 GOTO 465
460 D(I,L1) = 4
465  FOR M = 1 TO 21
470 M1 = E(L1,M)
475  IF M1 = 0 GOTO 535
480  IF M1 = I GOTO 530
485  IF D(I,M1) > 3 GOTO 495
490 D(I,M1) = 3
495  FOR T = 1 TO 21
500 T1 = E(M1,T)
505  IF T1 = 0 GOTO 530
510  IF T1 = I GOTO 525
515  IF D(I,T1) > 2 GOTO 525
520 D(I,T1) = 2
525  NEXT T
530  NEXT M
535  NEXT L
540  NEXT K
545  NEXT J
550  NEXT I
555  FOR I = 1 TO ND
560  FOR J = 1 TO ND
565  IF I = J THEN 575
570  IF D(I,J) = 0 THEN D(I,J) =
     2
575  NEXT J
580  NEXT I
585  REM ** SYMMETRY**
590  FOR I = 1 TO ND
595  FOR J = 1 TO ND
600  IF D(I,J) > D(J,I) THEN D(J,
     I) = D(I,J)
605  IF D(J,I) > D(I,J) THEN D(I,
     J) = D(J,I)
610  NEXT J
615  NEXT I
```

```
620  GOSUB 625: GOTO 645
625  HOME
630  PRINT : PRINT
635  PRINT "           LAYOUT EQUI
     VALENT": PRINT "           RE
     LATIONSHIP CHART": PRINT "
               ------------------":
      PRINT
640  RETURN
645 IC = 0
650  FOR I = 1 TO ND
655  PRINT "BETWEEN DEPT.# ";I
660  FOR J = 1 TO ND
665  IF I = J THEN 680
670  PRINT "            AND DEPT.#
      ";J;" LAYREL= ";D(I,J)
675 IC = IC + 1
680  IF IC = 12 THEN  PRINT : PRINT
     "HIT 'RETURN' TO CONTINUE": GET
     Y$:IC = 0: GOSUB 625: PRINT
     "BETWEEN DEPT.# ";I
685  NEXT J
690  NEXT I
695  PRINT : PRINT "HIT 'RETURN'
     TO CONTINUE": GET Y$
700  HOME
705  REM ** RELATIONSHIP CHART EV
     ALUATION PROCESS
710  REM **SUBTRACT REL. CHART W.
     R.T. PRODUCT - REL. CHART W.
     R.T. ADJACENT DEPTS.
715  FOR I = 1 TO ND - 1
720  FOR J = I + 1 TO ND
725  IF DD(I,J) = 6 AND D(I,J) <
      > 6 THEN  GOSUB 1155: GOTO
     985
730  IF DD(I,J) = 1 AND D(I,J) =
     6 THEN  GOSUB 1180: GOTO 985

735  NEXT J
740  NEXT I
745  FOR I = 1 TO ND - 1
750  FOR J = I + 1 TO ND
755 X = DD(I,J) - D(I,J)
760  NEXT J
765  NEXT I
```

```
770  PRINT : PRINT : PRINT "    E
     VALUATION SCORING": PRINT "
        ----------------------": PRINT

775 L = 0:LT = 0
780 IC = 0
785 N1 = ((ND * ND) - ND) / 2
790  DIM JX(5),ME(5,N1,2)
795  FOR I1 = 1 TO 5:JX(I1) = 0: NEXT
     I1
800  FOR I = 1 TO ND - 1
805  FOR J = I + 1 TO ND
810 X = DD(I,J) - D(I,J)
815 L = L + 1
820 LS = 0
825  IF X <  = 0 THEN LS = 5: GOTO
     845
830  FOR I1 = 1 TO 4
835  IF X = I1 THEN  GOSUB 880: GOTO
     845
840  NEXT I1
845  PRINT "FROM DEPT ";I;" TO DE
     PT ";J;" EVAL SCORE= ";LS
850 IC = IC + 1
855  IF IC = 11 THEN  PRINT : PRINT
     : INPUT "HIT RETURN TO CONTI
     NUE";Y$:IC = 0
860 LT = LT + LS
865  NEXT J
870  NEXT I
875  GOTO 905
880  REM **SUBROUTINE EFFICIENCY*
     *
885  IF X = I1 THEN LS = (5 - I1)
     :JD = LS + 1:JX(JD) = JX(JD)
      + 1
890 J1 = JX(JD)
895 ME(JD,J1,1) = I:ME(JD,J1,2) =
     J
900  RETURN
905 L = 5 * L
910  PRINT : PRINT "A TOTAL EVALU
     ATION SCORE OF ";LT: PRINT :
      PRINT "OUT OF A POSSIBLE MA
     XIMUM OF ";L: PRINT : PRINT
     "WAS DETERMINED."
```

```
915  PRINT : PRINT : INPUT "HIT R
     ETURN TO CONTINUE";Y$: HOME

920  REM  ** DISPLAY OF DATA ** R
     ETURN
925  FOR I = 1 TO 5
930 Z = 0:R = 0
935  IF JX(I) = 0 THEN 980
940  HOME : PRINT : PRINT "IF THE
      FOLLOWING DEPTS.": PRINT : PRINT
     "BECAME CLOSER ---": PRINT :
      PRINT
945  FOR J = 1 TO JX(I)
950  PRINT : PRINT "          DEPT
     . ";ME(I,J,1);" & DEPT. ";ME
     (I,J,2)
955  NEXT J
960 Z = 6 - I:R = R + Z
965  PRINT : PRINT "THIS WOULD IN
     CREASE THE TOTAL": PRINT : PRINT
     "EVALUATION SCORE TO ";LT +
     (R * JX(I))
970  PRINT : PRINT "OUT OF A POSS
     IBLE MAXIMUM OF ";L: PRINT
975  PRINT : PRINT : INPUT "HIT R
     ETURN TO CONTINUE";Y$
980  NEXT I
985  HOME : PRINT : PRINT : PRINT
     : PRINT " NEXT STEP TO BE PE
     RFORMED "
990  PRINT "     1. EXIT PROGRAM"

995  PRINT "     2. INPUT NEW DAT
     A"
1000  PRINT : PRINT : PRINT "   E
     NTER CHOICE # ": GET X
1005  ON X GOTO 1020,10
1010  PRINT "CHOICE MUST BE 1 OR
     2": GOTO 985
1015  END
1020  HOME : END
1025  HOME : CLEAR : GOTO 10
1030  HOME : FOR X = 1 TO 5: PRINT
     : NEXT X
1035  PRINT "            PLANT DE
     SIGN"
```

```
1040  PRINT "           LAYOUT EVA
     LUATION"
1045  PRINT
1050  PRINT "            IEMS DEPA
     RTMENT"
1055  PRINT "              UNIVERS
     ITY": PRINT "
       OF": PRINT "            CEN
     TRAL FLORIDA"
1060  FOR X = 1 TO 3000: NEXT X: HOME

1065  RETURN
1070  STOP
1075  FOR I = I TO ND: HOME
1080  PRINT "FOR DEPT  #";I
1085  FOR J = 1 TO 12
1090  INPUT "NEW ADJACENT DEPT. =
     ";E(I,J)
1095  IF E(I,J) = 0 THEN  RETURN

1100 N%(I) = N%(I) + 1
1105  NEXT J
1110  RETURN
1115  PRINT : INPUT "DO YOU WANT
     TO MAKE ANY CHANGES(Y OR N)
     ";Y$
1120  IF Y$ = "N" GOTO 1150
1125  IF Y$ <  > "Y" THEN 1115
1130  INPUT "CHANGE RELVAL BET. D
     EPT. ";I
1135  INPUT "                AND D
     EPT. ";J
1140  INPUT "
       TO ";DD(I,J)
1145  PRINT "   *** CHANGE IMPLEM
     ENTED ***": GOTO 1115
1150  RETURN
1155  HOME
1160  FOR T = 1 TO 5: PRINT : NEXT
     T
1165  PRINT "   DEPT.# ";I;" AND
     DEPT.# ";J: PRINT "   SHOULD
      BE ADJACENT IN, ANY": PRINT
     "   LAYOUT ARRANGEMENT.": PRINT
     "   THE LAYOUT IN HAND DOES
     NOT": PRINT "   FULFILL THIS
      REQUIREMENT."
```

```
1170  PRINT : PRINT : PRINT "HIT
      'RETURN' TO CONTINUE";: GET
      Y$
1175  RETURN
1180  HOME
1185  FOR T = 1 TO 5: PRINT : NEXT
      T
1190  PRINT "     DEPT.# ";I;" AN
      D DEPT.# ";J: PRINT "     CA
      NNOT BE ADJACENT IN ANY": PRINT
      "     LAYOUT ARRANGEMENT.": PRINT
      "     THE LAYOUT IN HAND DOE
      S NOT": PRINT "    FULFILL T
      HIS REQUIREMENT."
1195  PRINT : PRINT : PRINT "HIT
      'RETURN' TO CONTINUE": GET Y
      $
1200  RETURN
```

Case Example

A company consists of five production departments (#1 through #5).

The Industrial Engineer needs to evaluate a departmental layout with respect to satisfying a given relationship chart so that he can rearrange them with respect to satisfying production requirements.

After loading the program and typing RUN, the screen displays the following:

```
RUN

          PLANT DESIGN
       LAYOUT EVALUATION

        IEMS DEPARTMENT
          UNIVERSITY
              OF
          CENTRAL FLORIDA
```

This is followed by a brief statement of program instruction.

```
DO YOU NEED INSTRUCTIONS (Y OR N) Y


THIS PROGRAM IS DESIGNED TO EVALUATE
A DEPARTMENTAL ARRANGEMENT (LAYOUT)
WITH RESPECT TO SATISFYING A
RELATIONSHIP CHART TO BE SUPPLIED
BY THE USER. EVALUATION CRITERIA
IS THE PROXIMITY BETWEEN DEPARTMENTS.

PROGRAM ACCEPTS A RELATIONSHIP CHART
USING THE FOLLOWING 'RELVAL'S :
              RELVAL KEY
6: ABSOLUTELY CLOSE 3: ORDINARY CLOSE
5: ESPECIALLY CLOSE 2: UNIMPORTANT
4: IMPORTANT        1: UNDESIRABLE
```

```
IT ACCEPTS DATA FOR THE LAYOUT IN
THE FORM OF DEPT.# AND THE #'S OF
DEPTS. ADJACENT TO IT.

PROGRAM SCORES THE LAYOUT AND
RECOMMENDS IMPROVEMENTS.

HIT ' RETURN' WHEN READY
```

The required data is now entered.

```
 ENTER THE # OF DEPARTMENTS 5

ENTER RELVAL BETWEEN DEPT. 1
                 AND DEPT. 2 = ?2
                 AND DEPT. 3 = ?5
                 AND DEPT. 4 = ?5
                 AND DEPT. 5 = ?2
ENTER RELVAL BETWEEN DEPT. 2
                 AND DEPT. 3 = ?2
                 AND DEPT. 4 = ?4
                 AND DEPT. 5 = ?2
ENTER RELVAL BETWEEN DEPT. 3
                 AND DEPT. 4 = ?2
                 AND DEPT. 5 = ?5
ENTER RELVAL BETWEEN DEPT. 4
                 AND DEPT. 5 = ?2

DO YOU WANT TO MAKE ANY CHANGES(Y OR N) Y
```

Corrections are made by entering the numbers of the departments which changes will be made between and the corresponding corrected RELVAL.

```
CHANGE RELVAL BET. DEPT. 1
               AND DEPT. 2
                   TO 6
   *** CHANGE IMPLEMENTED ***

DO YOU WANT TO MAKE ANY CHANGES(Y OR N) N

HIT 'RETURN' TO CONTINUE
```

A brief set of program instructions is now given.

```
          INPUT DATA FOR
      LAYOUT TO BE EVALUATED

   FOR EACH DEPT., ENTER THE # OF
   CORRESPONDING ADJACENT DEPTS.

NOTE:
-----

     . NO. OF ADJACENT DEPTS.NOT TO
       EXCEED 20.

     . ENTER '0' TO END SEQUENCE OF
       ADJACENT DEPTS.

HIT 'RETURN' TO CONTINUE
```

The required data is now entered.

```
FOR DEPT. # 1
     ADJACENT DEPT. 1 IS ?5
     ADJACENT DEPT. 2 IS ?0

DO YOU WANT TO MAKE CHANGES, (Y OR N)?N
```

Corrections are made by entering the corrected adjacent department numbers.

If the RELVAL between two departments is equal to six and they are not adjacent according to the layout REL Chart, a message informs the user of this case and the evaluation stops.

```
DEPT.# 1 AND DEPT.# 2
SHOULD BE ADJACENT IN ANY
LAYOUT ARRANGEMENT.
THE LAYOUT IN HAND DOES NOT
FULFILL THIS REQUIREMENT.
```

If the RELVAL between two departments is equal to one and the departments are adjacent according to the layout REL Chart, a message informs the user of this case and the evaluation stops.

```
DEPT.# 1 AND DEPT.# 5
CANNOT BE ADJACENT IN ANY
LAYOUT ARRANGEMENT.
THE LAYOUT IN HAND DOES NOT
FULFILL THIS REQUIREMENT.
```

The remaining data is now entered.

```
FOR DEPT. # 2
     ADJACENT DEPT. 1 IS ?4
     ADJACENT DEPT. 2 IS ?5
     ADJACENT DEPT. 3 IS ?0
FOR DEPT. # 3
     ADJACENT DEPT. 1 IS ?4
     ADJACENT DEPT. 2 IS ?0

FOR DEPT. # 4
     ADJACENT DEPT. 1 IS ?2
     ADJACENT DEPT. 2 IS ?3
     ADJACENT DEPT. 3 IS ?0

FOR DEPT. # 5
     ADJACENT DEPT. 1 IS ?1
     ADJACENT DEPT. 2 IS ?2
     ADJACENT DEPT. 3 IS ?0
```

While calculating the Layout Equivalent REL Chart, the program will display the following:

```
YOUR COMPUTER IS CALCULATING

PLEASE STAND BY
```

After the period in which computation takes place, the results are displayed.

```
                LAYOUT EQUIVALENT
                RELATIONSHIP CHART
                ------------------

BETWEEN DEPT.# 1
              AND DEPT.# 2 LAYREL= 5
              AND DEPT.# 3 LAYREL= 3
              AND DEPT.# 4 LAYREL= 4
              AND DEPT.# 5 LAYREL= 6
BETWEEN DEPT.# 2
              AND DEPT.# 1 LAYREL= 5
              AND DEPT.# 3 LAYREL= 5
              AND DEPT.# 4 LAYREL= 6
              AND DEPT.# 5 LAYREL= 6
BETWEEN DEPT.# 3
              AND DEPT.# 1 LAYREL= 3
              AND DEPT.# 2 LAYREL= 5
              AND DEPT.# 4 LAYREL= 6
              AND DEPT.# 5 LAYREL= 4

BETWEEN DEPT.# 4
              AND DEPT.# 1 LAYREL= 4
              AND DEPT.# 2 LAYREL= 6
              AND DEPT.# 3 LAYREL= 6
              AND DEPT.# 5 LAYREL= 5
BETWEEN DEPT.# 5
              AND DEPT.# 1 LAYREL= 6
              AND DEPT.# 2 LAYREL= 6
              AND DEPT.# 3 LAYREL= 4
              AND DEPT.# 4 LAYREL= 5

HIT 'RETURN' TO CONTINUE
```

The evaluation scoring is now displayed.

```
     EVALUATION SCORING
     ------------------

FROM DEPT 1 TO DEPT 2 EVAL SCORE= 5
FROM DEPT 1 TO DEPT 3 EVAL SCORE= 3
FROM DEPT 1 TO DEPT 4 EVAL SCORE= 4
FROM DEPT 1 TO DEPT 5 EVAL SCORE= 5
FROM DEPT 2 TO DEPT 3 EVAL SCORE= 5
FROM DEPT 2 TO DEPT 4 EVAL SCORE= 5
FROM DEPT 2 TO DEPT 5 EVAL SCORE= 5
FROM DEPT 3 TO DEPT 4 EVAL SCORE= 5
FROM DEPT 3 TO DEPT 5 EVAL SCORE= 4
FROM DEPT 4 TO DEPT 5 EVAL SCORE= 5

A TOTAL EVALUATION SCORE OF 46

OUT OF A POSSIBLE MAXIMUM OF 50

WAS DETERMINED.


HIT RETURN TO CONTINUE
```

Guidelines for rearrangement with respect to satisfying production requirements are now displayed.

```
IF THE FOLLOWING DEPTS.
BECAME CLOSER ----

          DEPT. 1 & DEPT. 3
THIS WOULD INCREASE THE TOTAL
EVALUATION SCORE TO 48
OUT OF A POSSIBLE MAXIMUM OF 50

HIT RETURN TO CONTINUE
IF THE FOLLOWING DEPTS.
BECAME CLOSER ---

          DEPT. 1 & DEPT. 4
          DEPT. 3 & DEPT. 5
THIS WOULD INCREASE THE TOTAL
EVALUATION SCORE TO 48
OUT OF A POSSIBLE MAXIMUM OF 50

HIT RETURN TO CONTINUE
```

Finally, program options are displayed.

```
NEXT STEP TO BE PERFORMED
    1. EXIT PROGRAM
    2. INPUT NEW DATA

  ENTER CHOICE #
```

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research has been concerned with the development of micro-software for use in plant layout design. Five programs were developed in this study which include analysis, arrangement, and evaluation techniques.

Effective analytical techniques such as CRAFT (Computerized Relative Allocation of Facilities Technique) and CORELAP (Computerized-Relationship Planning), which were originally designed for main-frame computers, were adapted to operate on the microcomputer.

The From/To Chart and the Relationship Chart are analysis type programs. They can be used alone or as input to CRAFT and CORELAP. CRAFT is an arrangement/improvement type program which requires an initial layout. CORELAP is an arrangement/construction type program which constructs a layout arrangement from "scratch". These layout arrangements can be evaluated by using the evaluation program, EVAL.

The use of micro computers could result in quicker, cheaper, and more effective analysis of layout changes because the supporting software is available.

Recommendations

During the course of my study, I have come across certain areas which should be further investigated. The following is a summary of recommended research:

1. Apply graphical techniques using high resolution graphics to display the layout arrangement to the user.

2. Develop a program/methodology by which same techniques can be used to accomodate more input data as it becomes available.

3. Analyze the effect of different arrangement techniques for use in construction programs, such as CORELAP.

4. Develop an evaluation program which would use other criteria than relationship values, such as backtracking and safety.

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